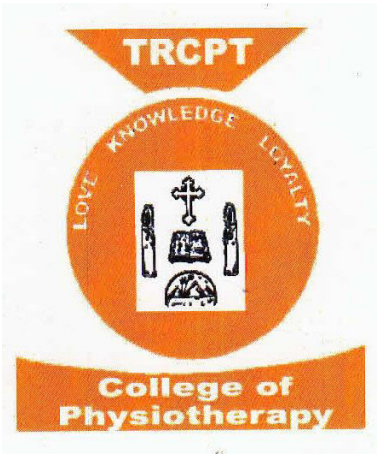
THE EFFECT OF INCLINED BOARD PLYOMETRICS ON JUMP PERFORMANCE IN YOUNG ELITE ATHLETES



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DESSERTATION SUBMITTED TO

THE TAMILNADU DR. M.G.R. MEDICAL UNIVERSITY

TOWARDS PARTIAL FULFILLMENT AS A REQUIREMENT FOR THE DEGREE

MASTER OF PHYSIOTHERAPY
(PHYSIOTHERAPY IN SPORTS)

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THE EFFECT OF INCLINED BOARD PLYOMETRICS ON JUMP PERFORMANCE IN YOUNG ELITE ATHLETES

Internal Examiner:

External Examiner:

A dissertation submitted in partial fulfillment as a requirement for the degree

MASTER OF PHYSIOTHERAPY

To

THE TAMIL NADU DR. M.G.R. MEDICAL UNIVERSITY

CHENNAI

MAY – 2017

CERTIFICATE

This is to certify that the research work entitled **"THE EFFECT OF INCLINED BOARD PLYOMETRICS ON JUMP PERFORMANCE IN YOUNG ELITE ATHLETES"** was carried out by the candidate with the (**REG NO: 271550102**) Master of physiotherapy student at Thanthai Roever Collage of Physiotherapy, Perambalur, submitted to Tamil Nadu Dr. M.G.R. Medical University, Chennai towards the partial fulfillment as a requirement for the Degree Master of Physiotherapy (MPT-SPORTS).

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This is to certify that the research work **"THE EFFECT OF INCLINED BOARD PLYOMETRICS ON JUMP PERFORMANCE IN YOUNG ELITE ATHLETES"** was carried out by the candidate with the **(REG NO: 271550102)** Thanthai Roever College of Physiotherapy Perambalur under the guidance of me towards the partial fulfillment as a requirement for the degree Master of Physiotherapy Submitted to The Tamil Nadu Dr. MGR Medical University Chennai. (MPT - SPORTS).

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INTRODUCTION

POWER is the king of the sporting world. Plyometrics is a type of exercise designed to produce fast and powerful movements. They are generally used by athletes to improve performance in sports, especially those that involve speed, quickness and power.[1]

Two forms of plyometrics have been evolved. The first version of plyometrics was created by Yuri Verkhoshansky where he defined it as shock method. In this the athlete would drop down from a height and experience a "shock" on landing. This in turn would bring about a forced, involuntary eccentric contraction which would then immediately get switched to concentric contraction as the athlete jumped upward. The landing and takeoff time would be executed in an extremely short period of time, the range of 0.1- 0.2 seconds.[2]

The second version of plyometrics, seen to a very great extent in the United States, relates to doing any and all forms of jumps regardless of execution time. Such jumps cannot be considered truly plyometric since the intensity of execution is much less and the time required for transitioning from the eccentric to the concentric contraction is much greater. Speed and strength are integral components of fitness found in varying degrees in all athletic movements. Simple combination of speed and strength is power.[2]

There are many benefits that can be gained through plyometric exercise:

- They help to achieve any athletic goal.
- They give legs and muscles intense exercise which guarantees to increase muscle potential.
- An increased muscular endurance an ability to burn calories would come to great use for someone hoping to build a weight loss routine.
- It builds up explosive amounts of intense energy.
- It does not require any expensive exercise equipment. Anything that is needed can be easily found lying around the house.
- Plyometric exercising is simply utilizing the muscular energy that it takes to jump at one's own exercising advantages.[2]

POWER- Power is the rate at which work is done. It is the work/time ratio.[8]

Components affecting power**-** Strength and speed are required to produce power. Both of these can be increased through the use of appropriate and systematic training. A body's skeletal musculature is made up of several types of fibers. Type I fibers, the so-called slow-twitch (ST) muscle fibers, are associated with less powerful, more enduring functions. These fibers, being more aerobic in nature, take longer to develop force and to fatigue.

Type II muscle fibers, the so-called fast-twitch (FT) fibers, are associated with shorter bursts of explosive action. These fibers, which are used during anaerobic performance, develop force more quickly and fatigue more easily. Type II fibers are further subdivided into Type II a and Type II b fibers, with a-types having greater ability for aerobic metabolism and more resistance to fatigue.[8]

The proportion and distribution of FT fibers throughout the body depends to a great extent on genetic makeup. The average person has an approximate 50-50 split of FT and ST fibers throughout the body. Athletes who excel at power events tend to have a higher percentage of FT fibers, however, and those who excel at endurance events tend to have a higher percentage of ST fibers, compared to the average person.[8]

The number of ST and FT fibers cannot be altered. Stimulating the FT fibers with explosive training improves their ability to fire or contract powerfully. This is the primary rationale for training for increased power. We *can* improve our FT fibers.[8]

The ankle joint proposes of 15 to 25 degrees of dorsiflexion and 30 to 50 degrees of plantar flexion. In such a case when the movement is done on an inclined surface, the plantar and the dorsiflexion both are altered. This improves the range of motion of the ankle joint and helps in the jump performance of the athlete.

The Physiology of Plyometrics

Plyometrics refers to exercise that enables a muscle to reach maximum force in the shortest possible time. The muscle is loaded with an eccentric (lengthening) action, followed immediately by a concentric (shortening) action.[9]

How Plyometric Exercises Work

A muscle that is stretched before a concentric contraction, will contract more forcefully and more rapidly. A classic example is a dip" just prior to a vertical jump. By lowering the center of gravity quickly, the muscles

involved in the jump are momentarily stretched producing a more powerful movement. Two models have been proposed to explain this phenomenon.[9]

1) **Mechanical Model**
2) **Neurophysical Model**

Mechanical Model:

In this model, elastic energy is created in the muscles and tendons and stored as a result of a rapid stretch. This stored energy is then released when the stretch is followed immediately by a concentric muscle action. According to Hill the effect is like that of stretching a spring, which wants to return to its natural length. The spring in this case is a component of the muscles and tendons called the series of elastic component.[9]

Neurophysical Model:

When a quick stretch is detected in the muscles, an involuntary, protective response occurs to prevent overstretching and injury. This response is known as the **stretch reflex**. The stretch reflex increases the activity in the muscles undergoing the stretch or eccentric muscle action, allowing it to act much more forcefully. The result is a powerful braking effect and the potential for a powerful concentric muscle action. If the concentric muscle action does not occur immediately after the pre-stretch, the potential energy produced by the stretch reflex response is lost. (i.e. if there is a delay between dipping down and then jumping up, the effect of the counter-dip is lost).[9]

It is thought that both the mechanical model (series elastic component) and the Neurophysical model (stretch reflex) increase the rate of force production during plyometrics exercises.[9]

Plyometric training is defined as a quick, powerful movement involving an eccentric contraction, following immediately by an explosive concentric contraction. This is accomplished through the stretch shortening cycle or an eccentric contraction. The eccentric concentric coupling phase is also referred to as the integrated performance paradigm, which states that in order to move with precision, forces must be loaded stabilized and then unloaded/ accelerated. Plyometric exercise stimulates the body's proprioceptive and elastic properties to generate force output in a minimum amount of time.[9]

The Stretch-Shortening Cycle

All plyometric movements involve **three** phases. The first phase is the pre-stretch or eccentric muscle action. Here, elastic energy is generated and stored. The second phase is the time between the end of the pre-stretch and the start of the concentric muscle action. This brief transition period from stretching to contracting is known as the **amortization** phase. The shorter this phase is, the more powerful the subsequent muscle contraction will be. The third and final phase is the actual muscle contraction. In practice, this is the movement the athletes desires the powerful jump or throw. This sequence of three phases is called the **stretch-shortening cycle**. In fact, plyometrics could also be called stretch-shortening cycle exercises.[9]

THE ECCENTRIC PHASE

The first stage of a plyometric movement can be classified as the eccentric phase, but it has also been called deceleration, loading, yielding, counter movement cocking phase. The phase increases muscle spindle activity by pre- stretching the muscle prior to activation. Potential energy is stored in the elastic components of the muscle during this loading phase. A slower eccentric phase prevents taking optimum advantage of the myo-static stretch reflex.[9]

THE AMORTIZATION PHASE

This phase involves dynamic stabilization and s the time between the end of the eccentric contraction (the loading or deceleration phase) and the initiation of the concentric (the unloading or force production phase). The amortization phase, sometimes referred to as the transition phase, is also referred to as the electromechanical delay between the eccentric and concentric contraction during which the muscle must switch from overcoming force to imparting force in the intended direction. A prolonged amortization phase results in less-than-optimum neuromuscular efficiency from a loss of elastic potential energy. A rapid switch from an eccentric contraction to a concentric contraction leads to a powerful response.[9]

THE CONCENTRIC PHASE

The concentric phase (the unloading phase) occurs immediately after the amortization phase and involves a concentric contraction resulting in enhanced muscular performance following the eccentric phase of muscular contraction. This occurs secondary to enhanced summation and re-utilization of elastic potential energy, muscle potentiation and contribution of the myostatic reflex.

The primary goal of plyometric training is to increase power. The track and field athletes that need to stress power development most of the jumpers and throwers, so their training should utilize a large number of plyometric drills. Power plyometrics emphasize the simultaneous application of maximum strength and quickness. The focus of movement is explosiveness. When doing jump repetitions, for example, the objective is t perform a set of jumps at high intensity, not to continue repetitions past the point of fatigue. Although plyometric training can be used for such purposes, the goal of power drills is not endurance. Explosiveness is greatest when the muscle is warmed and rested. It is better to do an extra set of an exercise than to add repetitions that are not done powerfully. Power plyometric drills include a variety of jumping movements. Plyometric jumps are designed to build explosive power and quickness, so the jumps themselves can be high impact, creating a strenuous workout. The series of plyometric jumps require balance and co-ordination to be done correctly. Some jumps include squat jumps, diagonal obstacle jumps. Single leg hops and tucks jumps.[9]

Plyometric trainings an effective mode of training as it enhances motor learning and neuromuscular efficiency promoting the excitability, sensitivity, and reactivity of the neuromuscular system to increase the rate of force production (power), motor unit recruitment, firing frequency (rate coding), and synchronization.

Plyometric training is not a particularly new training method. It is specific work for the enhancement of explosive power. It is a training method to be used in conjunction with other power development methods in a complete training program to improve the relationship between maximum strength and explosive power. How the plyometrics works is particularly interesting. It says that, when a muscle that is

stretched before a concentric contraction, will contract more forcefully and more rapidly. A classic example is an open "dip" just prior to a vertical jump by lowering the center of gravity quickly; the muscles involved in the jump are momentarily stretched producing a more powerful movement.[9-10]

Simple way to demonstrate the effect of the stretch-shortening cycle is to perform two vertical jumps. During the first vertical jump the athlete bends the knees and hips (eccentric muscle action or pre-stretch) and holds the semi-squat position for 3-5 seconds before jumping up vertically (concentric contraction) as high as possible. The 3-5 second delay increases the amortization phase. On the second jump the athlete bends the knees and hips to the same degree but immediately jumps up without a delay. This keeps the amortization phase to a minimum and makes best use of the stored elastic energy. The second jump will be higher.[9-10]

By making use of the stretch-shortening cycle, movements can be made more powerful and explosive. Plyometrics is simply a set of drills designed to stimulate the series elastic component over and over again preferably during movements that mimic those is the athletes sport.[9-10]

ELASTICITY- It refers to the materials ability to return to its original state after deformation (change in dimensions i.e. length and shape after removal of the deforming load, when a material is stretched, work is done (work = force x distance) and energy increases. An elastic material stores this energy and readily returns it as work so that the stretched elastic material can recoil immediately to its original dimensions after removal of the distractive forces.[11]

ELASTIC RECOIL- Elastic recoil is sometimes referred to as an "impulsive" and "springy" gait, rebounding along on compliant legs and unlocked knees. Instead of using all the body's energy, the leg and foot have a built-in "return energy" system for a significant amount of energy.[11]

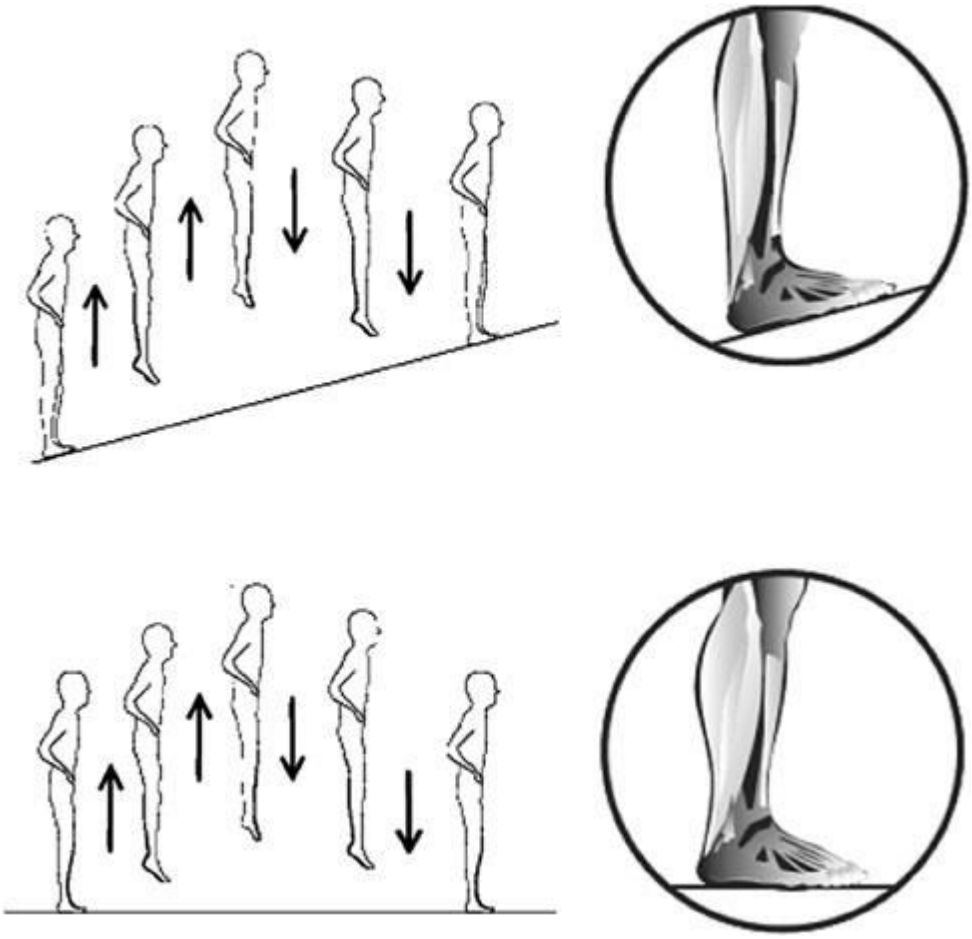
Inclined Plyometrics show great promises as a potential technique for improving explosive plantarflexion.[11]

The force-length relation is an important property of skeletal muscle to characterize its function, whereas for human muscles, the torque- angle relationships represent the maximum muscular capacity as a function of joint angle[3]

Modifications in the joint range of motion when performing a vertical jump could alter the range of muscle or tendon length during the movement. The behavior of the medial gastrocnemius (MGAS) fascicles has been described as a ''catapult action'' Particularly, the medial gastrocnemius fascicle length decreases at the instant of initial contact, it remains relatively constant during the braking phase followed by a decline during propulsion. Simultaneously, the ankle is initially in semi neutral position and then it is plantar flexed. However, it is known that isometric medial gastrocnemius force production is affected by muscle length and, in turn, by the angle of the ankle joint. Thus, the position of the ankle joint is of great importance for force production.[5]

The need for the generation of higher joint power output during performance of dynamic activities leads to force – length relationship of the plantar flexors during consecutive stretch shortening cycles of hopping.[5]

During jumping, medial gastrocnemius produces a large amount of force at a slow velocity because its length remains close to optimum range. However, the amount of force produced by the medial gastrocnemius could be much greater if jumping technique can be modified such that the muscle works at a length range near to its maximal force potential.[5]



1. POSITION OF ANKLE JOINT ON INCLINED SURFACE AND ON PLANE SURFACE

Increased dorsiflexion range of motion causes increase within the range of peak force production, which increases demand of work, causing a proportionate improvement in strength thereby improving the force production during jumping on the inclined surface.

Kubo et al 2007 proposed that there is an increase in tendon elongation after inclined board training which may lead to a higher amount of elastic energy stored during the braking phase which is released during the subsequent propulsive phase.

NEED FOR STUDY

The primary plantar flexor is the gastrocnemius. Previous research has suggested that dorsiflexion of the ankle facilitates a more optimal sarcomere length for the gastrocsolius muscle and would therefore be advantageous to force production. Performing plyometrics on an inclined surface means that the ankle is in a dorsiflexed position during the propulsion phase.[6]

Dorsiflexion causes the Achilles tendon to lengthen. This additional elongation during incline plyometrics may result in a greater energy return from the tendon[7]

The medial gastrocnemius muscle produces more force at more dorsiflexed ankle joint position. If this is the case, then changing the ankle range of motion when participants perform jumps toward greater lengths may improve medial gastrocnemius force and, in turn, jumping performance. Thus, the idea for modifying jumping technique to achieve optimal loads of muscles seems promising. To achieve this, subjects could perform jumps on an incline surface. Incline hopping might be more beneficial to improve jumping performance compared to the classical plane hopping as it takes greater advantage of the force–length properties of the gastrocnemius muscle.[5]

Plyometrics is a stretch shortening drill or cycle in which concentric contraction is followed by eccentric contraction. When muscles eccentrically contract or shorten and then immediately stretch or

lengthen, they produce maximal power ideal for athletic situations. It is a fast movement that happens over a short period.

Kubo et al 2007 proposed that there is an increase in tendon elongation after inclined board training which may lead to a higher amount of elastic energy stored during the braking phase which is released during the subsequent propulsive phase.

The muscles gastrocnemius and soleus both together are known as Triceps Surae. The triceps surae together eccentrically control dorsiflexion of the ankle while also supinating the subtalar joint after the foot is loaded in stance. These muscles provide supination torque that contributes in making the foot a rigid lever for push-off and continue to provide plantar flexion torque throughout heel rise and plantar flexion of the ankle as the ground reaction force moves to the metatarsal heads and toes.

The maximum torque generated by triceps surae is $r^2 = 0.69$[5]

Previous researchers have proved the effectiveness of plyometrics on the ankle joint on the plane surface in athletes. Plyometrics done on an inclined board may render a better performance in jumping activities.

HYPOTHESIS

NULL HYPOTHESIS-

10 Degree of inclined board plyometric training will not have an effect on the jumping performance among athletes.

The alteration in the length and the torque of the gastrocsolius muscle will not have any effect of the force production thereby showing no change in the jump performance.

ALTERNATE HYPOTHESIS-

10 Degree of inclined board plyometric training has an effect on the jumping performance among athletes.

Due to the raise in the angle of dorsiflexion, the gastrocsolius muscle lengthens. This alters the torque of the muscle and increases the force production thereby improving the jump performance.

AIM

To study the effect of inclined board plyometrics on jump performance among young elite athletes.

OBJECTIVES

1. To identify jump performance following 4 weeks of inclined board training to assess the power and strength by the four outcome measures of vertical jump test, static jump test, single leg hop time test and triple hop test.
2. To compare the pre and post findings of the outcome measures on the experimental group.
3. To compare the pre and post findings of the outcome measures on the control group.
4. To compare the post findings of the outcome measures on the experimental group and control group.

REVIEW OF LITERATURE

Kannas TM, Kellis E, Amiridis IG, Eur J Appl Physiol.**(2012)**[3] Jun;112(6):2353-61 studied the effects of incline plyometrics training on muscle activation and architecture during vertical jumping and maximum strength. Twenty male participants were divided in two training groups which followed after a 4 week training program. The incline plyometrics group (n = 10) trained by performing consecutive jumps on an inclined surface (15°) while the plane plyometrics group (n = 10) performed the same jumps on a plane surface. Both groups trained four times per week and performed 8 sets of 10 jumps in each session. Subjects performed squat jumps, counter movement jumps and drop jumps (DJ) prior to and immediately after the training period, while the electromyographic activity of the medial gastrocnemius and tibialis anterior muscles and the architecture of gastroc soleus were recorded.

Kannas, TM, Kellis, E, and Amiridis, IG (2011)[4] studied The Biomechanical differences between incline and plane hopping. J Strength Cond Res 25(12): 3334-3341, 2011-The need for the generation of higher joint power output during performance of dynamic activities led us to investigate the force-length relationship of the plantar flexors during consecutive stretch-shortening cycles of hopping. The hypothesis of this study was that hopping (consecutive jumps with the knee as straight as possible) on an inclined (15°) surface might lead to a better jumping performance compared with hopping on a plane surface (0°). Twelve active men performed 3 sets of 10 consecutive hops on both an incline and plane surface. Ground reaction forces; ankle and knee joint

kinematics; electromyographic (EMG) activity from the medial gastrocnemius (MG), soleus (Sol) and tibialis anterior (TA); and architectural data from the MG were recorded. The results showed that participants jumped significantly higher ($p < 0.05$) when hopping on an inclined surface (30.32 ± 8.18 cm) compared with hopping on a plane surface (27.52 ± 4.97 cm).

Chelly MS et al (2010) Oct.[28] studied the effects of in-season short-term plyometric training programme on leg power, jump and sprint performance of soccer players. The hypothesis was that the addition of an 8-week lower limb plyometric training programme (hurdle and depth jumping) to normal in-season conditioning would enhance measures of competitive potential. The subjects (23 males, age 19yrs) were randomly assigned to a control (normal training) group (gc; n=11) and an experimental group (gex; n= 12) that also performed biweekly plyometric training. There was a significant increase ($p < 0.05$) in thigh muscle volume, power and agility.

Sean P. Sankey (2008)[16] carried out a study to see the effects of two plyometric training programs of differently intensity on vertical jump performance in high school athletes. 18 healthy subjects were taken, and pre and post intervention was noted for all the subjects. It was found that greater improvement was noted for all the subjects. It was found that greater improvement for the INCR (periodised plyometric intensity) group. In conclusion, manipulation of exercise intensity for short duration plyometric training could be less significant than the intervention itself.

Goran Markovic et al (2007)[15] studied that Plyometric Training provides a statistically significant and practically relevant improvement in the vertical jump height thus justifying the application of Plyometric Training for the purpose of development of vertical jump performance in healthy individuals.

Markovic G, Jukic I, Milanovic D, et al. (2007)[14] studied Effects of sprint and plyometric training on muscle function and athletic performance and concluded that, short-term sprint training produces similar or even greater training effects in muscle function and athletic performance than does conventional plyometric training. Study supports for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

Avery D. Faigenbaum et al (2007)[17] compared the effect of resistance training v/s plyometric training on fitness performance. The mean age group was 12-15 yrs. The study conducted on 27 subjects concluded that the addition of plyometric training to a resistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of lower body power in boys.

Terese L. Chmielewski et al. (2006)[22] in their study Plyometric Exercise in the Rehabilitation of Athletes: Physiological Responses and Clinical Application mentioned that in plyometric exercises, there is loading of the joints, and the tissue has to tolerate high forces. For the same reason, the players having any kind of acute inflammation or pain, immediate postoperative status, and joint instability were excluded from the study.

Michael G Miller et al.(2006)[18] studied Effect of 6 weeks Plyometric Training Program on Agility in which results improved for the T-test by 4.86% & is because of better motor unit recruitment or neural adaptations.

Kotzamanidis C.(2006)[23] in his study, Effect of plyometric training on running performance and vertical jumping in prepubertal boys, concluded that, plyometric exercises can improve SJ and RV in prepubertal boys. More specifically, this program selectively influenced the maximum velocity phase, but not the acceleration phase.

Michael G. Milleret et al (2006)[18] studied the effects of a 6 week plyometric training program on agility and found that the plyometric training group had quicker posttest times compared to the control group for the agility tests. The plyometric training group performed in a six week plyometric raining program. 28 subjects participated in the training, ad were randomly assigned to two groups, a plyometric training group and a control group. Subjects were at least 18 yrs of age, free of lower extremity injuries.

Herrero JA, Izquierdo M, Maffiuletti NA, et al.(2006)[29] in their study Electro stimulation and plyometric training effects on jumping and sprint time concluded that, EMS alone or EMS combined with plyometric training leads to increase maximal strength and to some hypertrophy of trained muscles.

Michael G. Miller et al (2006)[18] said that plyometric training, when used with a periodized strength-training program, can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness, and overall proprioception.

Rahman Rahimi et al (2005)[21] proved that vertical jump height was measured by the stand and reach test (Chu, 1996). A vertical jump test was completed from a 2-foot standing position without a step into the jump. The subjects were allowed to use their hands as they desired. Three test jumps were completed, and the highest of these was recorded. This test was selected because it has high validity (0.80) and reliability (0.93) This study clearly illustrates the close working relationship between neuromuscular efficiency (e.g., multiple fiber recruitment and facilitating the stretching reflex) and dynamic strength performance. He concluded that plyometrics permits effective use of this strength to produce explosiveness in sports or events demanding speed and quickness.

Ademola O Abass (2005)[19] performed a plyometric training programme on 40 untrained individuals for over a period of 12 weeks. The study focused on the relationship among strength, endurance and power performance. Based on the finding of the study it was concluded that plyometrics training with repeated jumps horizontally and that which involves rebound jumping on the spot, are capable of improving leg muscle power.

Turner AM, Owings M, Schwane JA.(2003)[25] studied Improvement in running economy after 6 weeks of plyometric training and concluded that, 6 weeks of plyometric training improves running economy in regular but not highly trained distance runners.

Diallo O, Dore E, Duche P, et al.(2001)[24] in their study, Effects of plyometric training followed by a reduced training programme on physical performance in prepubescent soccer players concluded that, short-term plyometric training programmes increase athletic performances in prepubescent boys.

Fatouros IG, Jamurtas AZ, Leontsini D, et al.(2000)[26] in their study, Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength concluded that, use of a combination of traditional and Olympic-style weightlifting exercises and plyometric drills to improve vertical jumping ability and explosive performance in general.

Bosco et al (1979)[30] stated that plyometrics is considered a valuable training method in achieving conversion of maximal strength into power and has been specifically demonstrated to improve jumping ability.

DESIGN AND METHODOLOGY

- STUDY DESIGN – Randomized Control Trial
- STUDY SETTING – Deccan Gymkhana (F.C. Road-Pune)
- SAMPLE SIZE - 40
- SAMPELING METHOD –Simple Random Sampling
- TARGET POPULATION- Young Elite Athletes.
- MATERIALS- An Inclined Board of 10 degrees inclination and 90x60 cm size.

INCLUSION CRITERIA-

1. Athletes with the age group of 15yrs and above.
2. Athletes who have completed at least 1 full year of competitive athletics.
3. Subjects with good flexibility and strength of lower limbs
4. Subjects who have been involved in any professional active outdoor sporting activities involving running, jumping and speed movements.

EXCLUSION CRITERIA

1. Lower limb and Spine fractures and deformities.
2. Tightness and contractures of muscles n tendons of lower limbs.
3. Any intrinsic complains by the athlete that limits the athletic performance.

MATERIALS USED

1. Stop watch
2. Measuring tape
3. Goniometer
4. Inclined board
5. Chalk powder

METHODOLOGY

- After the approval of the dissertation topic by the College, the study was carried out at Perambalur District sports hostel.
- Necessary permissions were taken prior to starting the study at the setup.
- The subjects were selected as per the inclusion criteria and sample selection by Simple Random Sampling was done. The chit method was observed by dividing the chits into A and B and samples were asked to pick the chits. They were selected and grouped respectively in Group A and Group B. “A” being the experimental group and “B” being the control group.
- The warm-up protocol of the players was observed and the exercises common for Group A and Group B were taken into consideration.
- 40 subjects inclusive of the inclusion criteria were chosen and Group A consisted 21 samples and Group B consisted 19 samples.
- The exercises in which jumping was involved were identified and a protocol was designed involving them for both the groups.
- The experimental group performed the jumping exercises on the strong solid inclined board of 60cm X 80cm with an inclination of 10 degrees. A rubber sheet was attached on it to prevent falls from

the board while performing exercises on it.

- The outcome measures of vertical jump test, static jump test, single leg hop time test and triple hop test were assessed prior to the training protocol and following 4 weeks of training.
- The vertical jump test was conducted by placing a measuring tape vertically and the subjects were asked to jump against it. The static jump test and the vertical jump test were performed and recorded at the same time.
- The tests were done by asking the subjects to stand opposite to the vertical measuring tape. Then they were asked to squat for 5 seconds and jump as high as possible and touch the tape. Chalk powder was applied to each subject before they jumped and touched the tape. A person was asked to sit on a high seated chair beside the measuring tape and record the jump height. Two jumps were performed together consecutively. The first test was the static jump test which was done by squatting for 5 seconds and jumping while the second test was done immediately by jumping again as high as possible after landing from the static jump test. These tests were to measure the power and strength of the lower limbs.

- The third outcome measure was the single leg hop time test. In this test the time in seconds was noted while the subject performed three trials of single leg hop jump. Quickness was tested in this test.
- The last outcome measure was triple hop test which was again used to measure power of the lower limbs. In this test the horizontal distance was measured by the measuring tape as the subjects finished three trials of continuous three hops without a break. The distance at the end of the third hop was measured in every trial.

- All the tests were performed in three trials and the average of pre and post findings was taken into consideration for the statistical analysis.

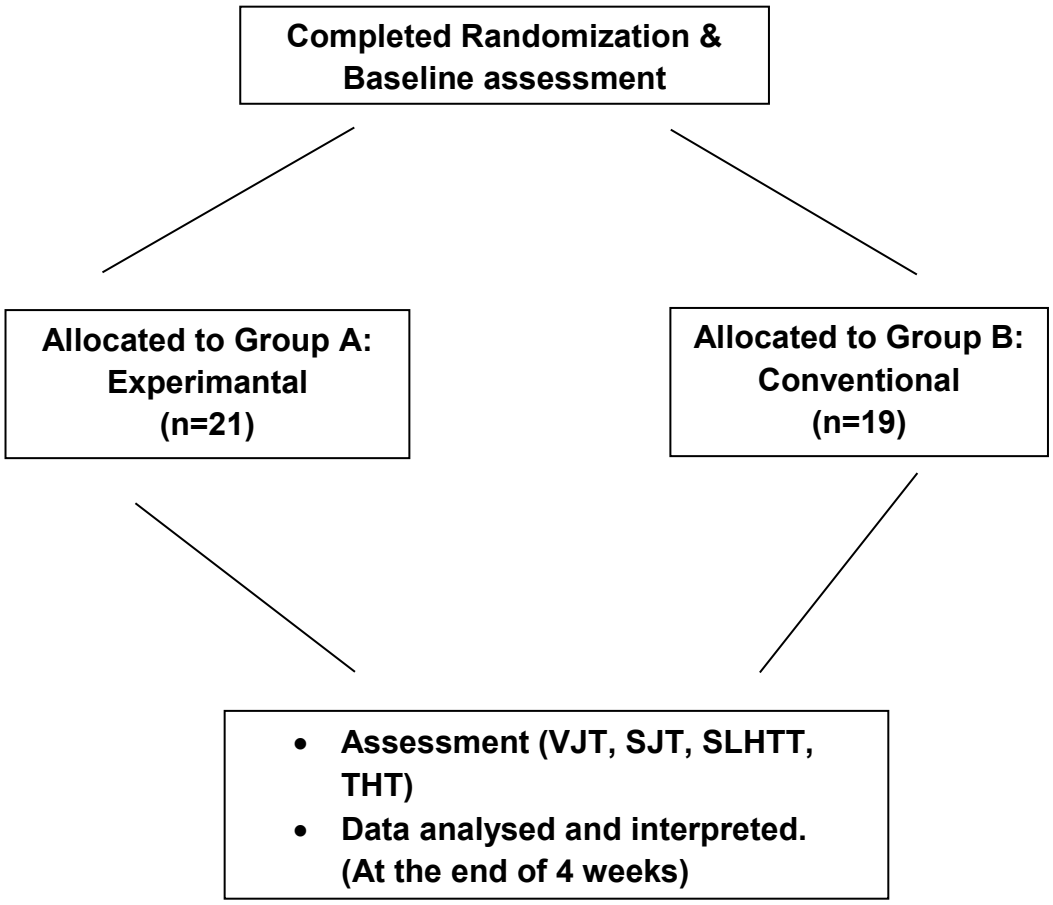


Fig-1. Study design and flow of the participants through each stages of the trial.

PROTOCOL FOR THE PLYOMETRIC TRAINING ON THE INCLINED BOARD

Sr No	Plyometric Exercise	Duration	Sessions
1	Single alternate leg on inclined board jumping (right-left)	4 mins 4 times / week	16 sessions
2	Double leg inclined board to ground jump	4 mins 4 times / week	16 sessions
3	Double leg two jumps on inclined board to ground	4 mins 4 times / week	16 sessions
4	Single alternate leg two jumps on board to ground (right-left)	4 mins 4 times / week	16 sessions

- In the first exercise, the subjects were asked to run across half court in a circular manner. The 10 degree inclined board was kept at a particular distance in between the running track. The subjects were asked to consciously put alternate legs on the board i.e first the right leg was taken and then the left leg was taken. This exercise continued for four minutes four times a week.
- The second exercise was done by jumping with both the legs on the inclined board. The subjects were asked to run in the same pattern as the first exercise in the circular manner and jump with both the legs together on the board and then land on the ground n then again continue running across the court. This was also done for four minutes four times a week.
- In the third exercise the subjects were asked to jump with both legs on the inclined board two times and then land on the ground for four minutes four times a week.
- In the last exercise, the subjects were asked to use alternate legs consciously and jump on the inclined board. The subject jumped with one leg two times and then landed on the ground. This was done by alternate legs for four minutes four times a week.

1. **AN INCLINED PLYOMETRIC BOARD WITH RUBBER SHEET**

DATA ANALYSIS AND INTERPRETATION

- In this study 21 subjects were included to study the effect of inclined board plyometric training and 19 were given similar training on the plane surface.
- Data was analyzed by using Primer software and normality distribution done by Epi Info 7 software.
- The Test of Significance such as "t" test between the groups was used after verifying the Bartlett's Test for Inequality of Population Variances was not significant.
- In case of Paired Values the Pittman's Test was used For Equality of Variances Before using the Paired "t" test.
- The statistical analysis was done using paired "t" test and unpaired "t" test.
- Intergroup significance was calculated by using unpaired "t" test and intragroup significance was calculated by paired "t" test.
- Data analysis was done and four test, (Vertical jump test, Static jump test, Single leg hop time test and Triple hop test) were recorded and tabulated.

Paired t test was used to compare the pre and post treatment:

$$t = \frac{\sum d}{\sqrt{Nd^2 - (\sum d)^2/N - 1}}$$

Where, $\sum d$ =The total of the difference

$\sum d^2$ =The total of the difference squared

$(\sum d)^2$ =The total of the squared differences

N = Total number of samples.

Unpaired t-test used to compare data between the groups:

$$t = \frac{\overline{x_1} \quad \overline{x_2}}{\sqrt{\frac{SD_1^2}{n_1} + \frac{SD_2^2}{n_2}}}$$

X1 = mean value of the first sample.

X2 = mean value of the second sample.

SD_1 =standard deviation of the first sample.

SD_2 =standard deviation of the second sample.

n_1- =sample size of the first sample.

n_2 =sample size of the second sample.

Table 1: COMPARISON OF PRE AND POST FINDINGS OF VERTICAL JUMP TEST IN GROUP A

Group	N	Mean (cm)	T value	Std deviation	P value
1	21	251.4		17.42	
2	21	252.1	-1.142	17.13	0.267

- Difference: -0.7143
- 95% confidential value: -2.019 to 0.5903
- t = -1.142 with 20 degrees of freedom; P = 0.267

Table: 1 Shows pre and post training mean of the vertical jump test of Group A. the pre training mean was 251.4 cm & post was 252.1 cm .So the difference was 0.7 cm. By using paired 't' test, the p value obtained is 0.267 which is >0.05 Thus it is proven statically that there is not much marked increase in the vertical jump height in group A after inclined board plyometric training.

Graph 1: COMPARISON OF PRE AND POST FINDINGS OF VERTICAL JUMP TEST IN GROUP A

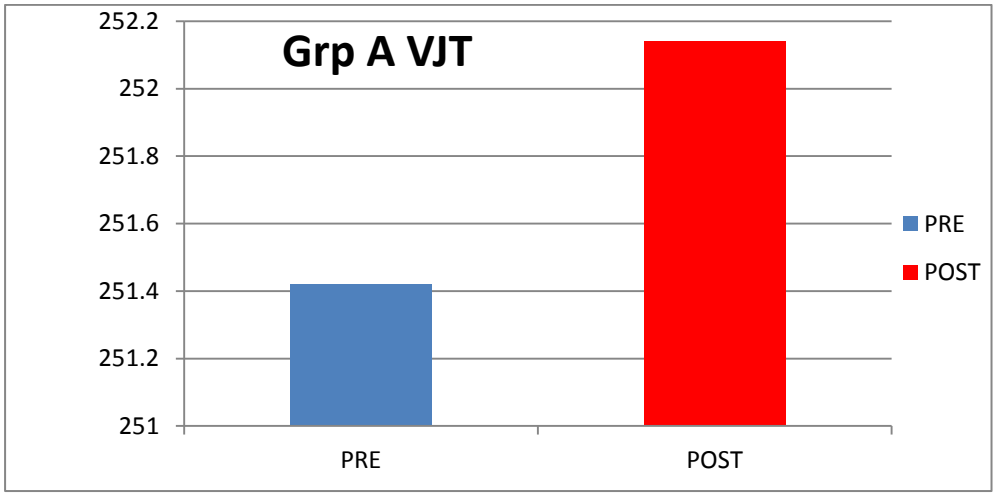


Table 2: COMPARISON OF PRE AND POST FINDINGS OF VERTICAL JUMP TEST IN GROUP B

Group	N	Mean (cm)	T Value	Std Deviation	P value
1	19	253.7		11.79	0.320
2	19	254.9	-1.211	12.25	

- Difference -1.211
- 95% confidential interval for difference: -3.697 to 1.276
- t = -1.023 with 18 degrees of freedom; P = 0.320

Table: 2 Shows pre & post training of VJT in group B pre training mean was 253.7 cm & post 254.9 cm. The difference was 1.2 cm. By using paired "t" test the P value obtained was p= 0.320 which is >0.05. Thus there is not a much marked difference in the improvement of the VJ height in group B.

Graph 2: COMPARISON OF PRE AND POST FINDINGS OF VERTICAL JUMP TEST IN GROUP B

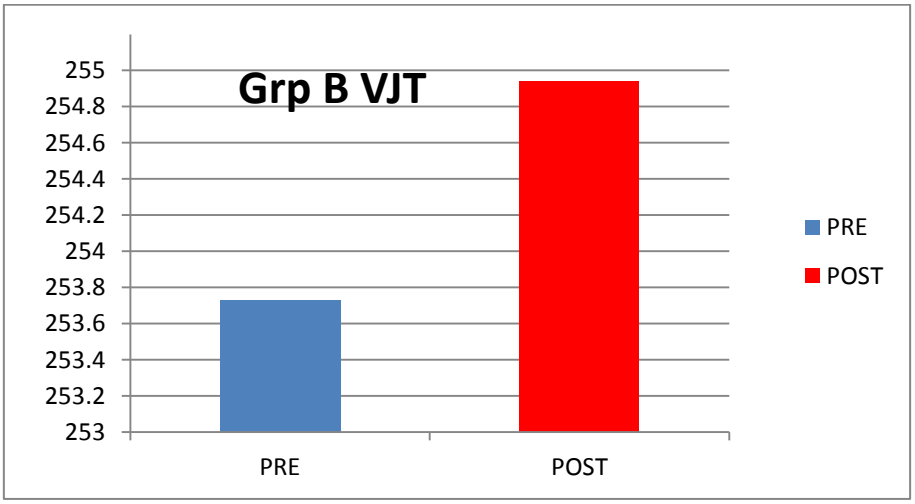


Table 3: COMPARISON BETWEEN POST FINDINGS OF VERTICAL JUMP TEST OF GROUP A & B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	0.7143	-0.381	2.866	0.705
2	19	1.211		5.159	

- Difference -0.4962
- 95% confidential interval for difference: -3.134 to 2.141
- t = -0.381 with 38 degrees of freedom; P = 0.705

Table: 3 Shows a comparison between the post training of the group A & B of VJT. The difference is -0.5. By using unpaired "t" test, the P values obtained was p=0.70 which is >0.05. Thus, statically there is not much difference in the improvement of the VJ of Group A with Group B.

GRAPH 3: COMPARISON BETWEEN POST FINDINGS OF VERTICAL JUMP TEST OF GROUP A & B

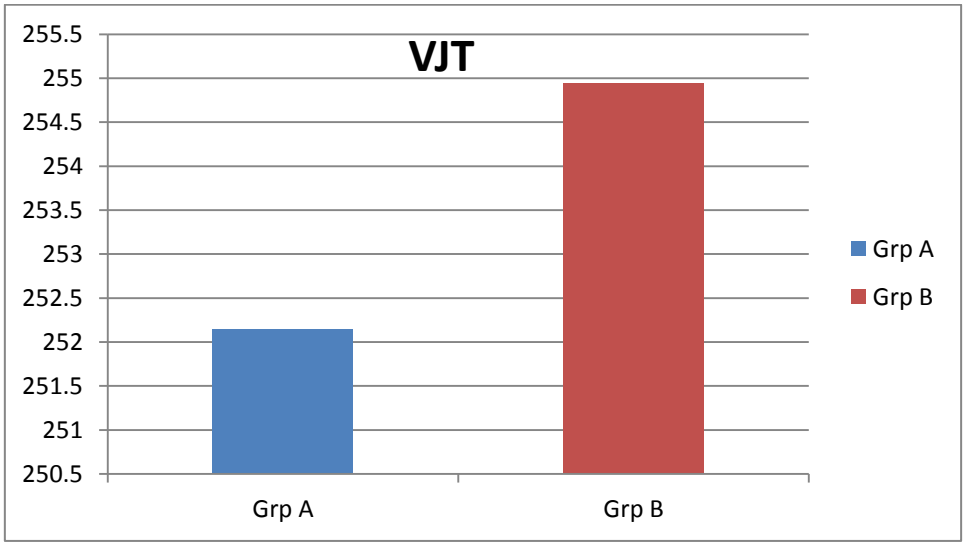


Table 4: COMPARISON OF PRE AND POST FINDINGS OF STATIC JUMP TEST IN GROUP A

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	251.3		17.86	
2	21	252.9	-2.568	17.29	0.018

- Difference -1.619
- 95% confidential interval for difference: -2.934 to -0.3039
- t = -2.568 with 20 degrees of freedom; P = 0.018

Table: 4 Shows pre & post training of SJT in group A. Pre training was 251.3 cm &post was 252.9cm.The difference obtained is 1.6 cm. By applying the paired "t" tests the P value obtained was 0.018 which is <0.05. This shows slight improvement in the static jump test in group A after the Inclined Board plyometric training.

Graph 4: COMPARISON OF PRE AND POST FINDINGS OF STATIC JUMP TEST IN GROUP A

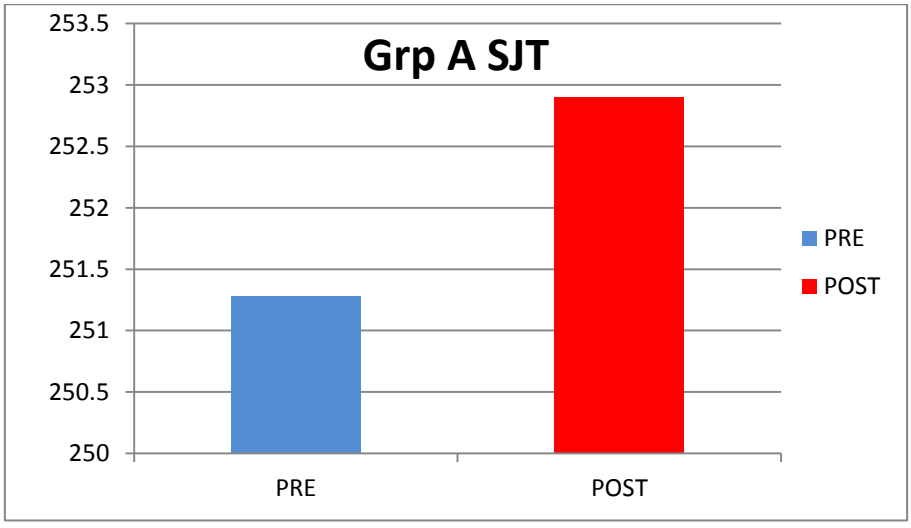


Table 5: COMPARISON OF PRE AND POST FINDINGS OF STATIC JUMP TEST IN GROUP B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	19	254.7		11.95	
2	19	255.5	-0.675	11.72	0.508

- Difference -0.7368
- 95% confidential interval for difference: -3.031 to 1.557
- t = -0.675 with 18 degrees of freedom; P = 0.508

Table: 5 Shows the pre & post training of SJT in group B. Pre training score was 254.7 cm & post was 255.5 cm. The difference noted was obtained was 0.508 which is >0.05. Thus statistically there is no improvement in the SJ height in Group B.

Graph 5: COMPARISON OF PRE AND POST FINDINGS OF STATIC JUMP TEST IN GROUP B

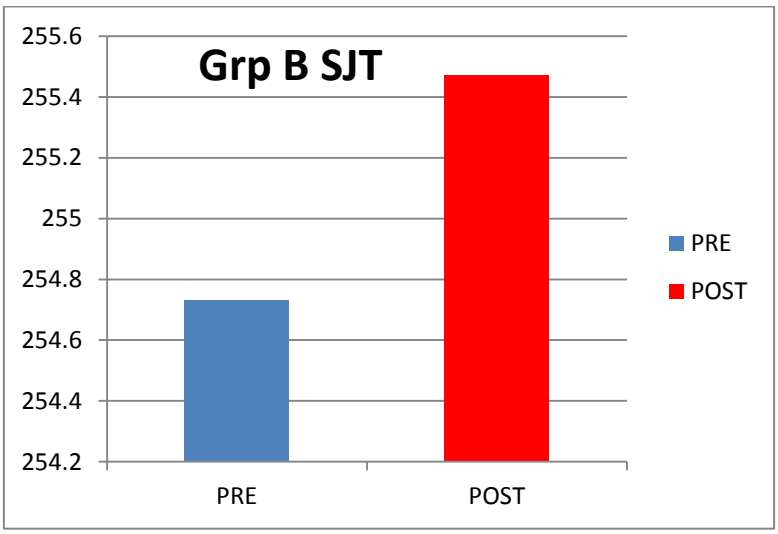


Table 6: COMPARISON BETWEEN POST FINDINGS OF STATIC JUMP TEST OF GROUP A & B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	1.619		2.889	
2	19	0.7368	0.717	4.759	0.478

- Difference 0.8822
- 95% confidence interval for difference: -1.61 to 3.375
- t = 0.717 with 38 degrees of freedom; P = 0.478

Table: 6 Shows a comparison between post training of group A & B for SJT. The mean post of Group A is 1.61 & that of group B is 0.73. The difference between the two is 0.88. By using the unpaired "t" test, the P value obtained was 0.478 which is > 0.05 hence; statistically there is no difference in the static jump performance of group A & B.

Graph 6: COMPARISON BETWEEN POST FINDINGS OF STATIC JUMP TEST OF GROUP A & B

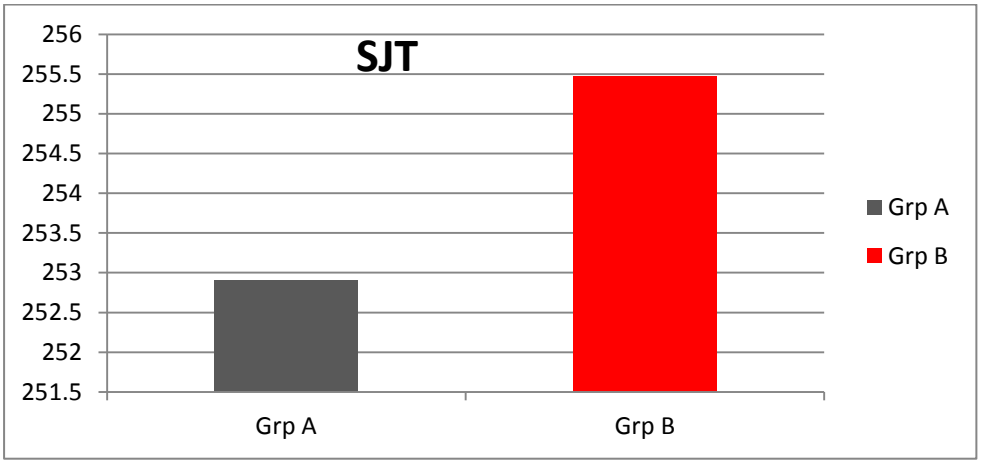


Table 7: COMPARISON OF PRE AND POST FINDINGS OF SINGLE LEG HOP TIME TEST IN GROUP A

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	1.129	3.026	0.4845	0.007
2	21	0.8619		0.3052	

- Difference 0.2667
- 95% confidential interval for difference: 0.08283 to 0.4505
- t = 3.026 with 20 degrees of freedom; P = 0.007

Table: 7 Shows pre & post training of SLHTT in group A. Pre score is 1.129 sec & Post score is 0.86 sec. The difference measured is -0.26. By applying the paired "t" test, the p value obtained is 0.007 which is <0.05. Thus statistically, the test is significant and there is a difference in the improvement of the pre & post training of the Inclined Board Plyometric training.

Graph 7: COMPARISON OF PRE AND POST FINDINGS OF SINGLE LEG HOP TIME TEST IN GROUP A

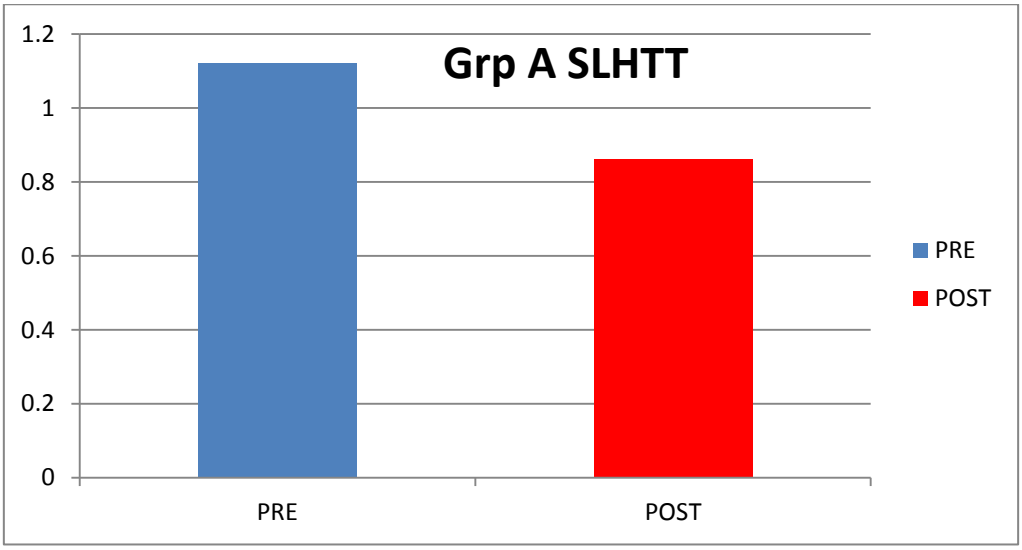


Table 8: COMPARISON OF PRE AND POST FINDINGS OF SINGLE LEG HOP TIME TEST IN GROUP B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	19	0.9237		0.288	
2	19	08605	1.022	0.3507	0.320

- Difference 0.06316
- 95% confidential interval for difference: -0.0667 to 0.193
- t = 1.022 with 18 degrees of freedom; P = 0.320

Table: 8 Shows pre &post training mean of SLHTT group B. Pre score is 0.923 sec & post score is 0.86 sec. The difference noted is -0.06. Using the paired "t" test, the p value obtained is 0.32>0.05. Thus this test is not improvement in the SLHTT of group B. There is no increase in the SLHT of group B.

Graph 8: COMPARISON OF PRE AND POST FINDINGS OF SINGLE LEG HOP TIME TEST IN GROUP B

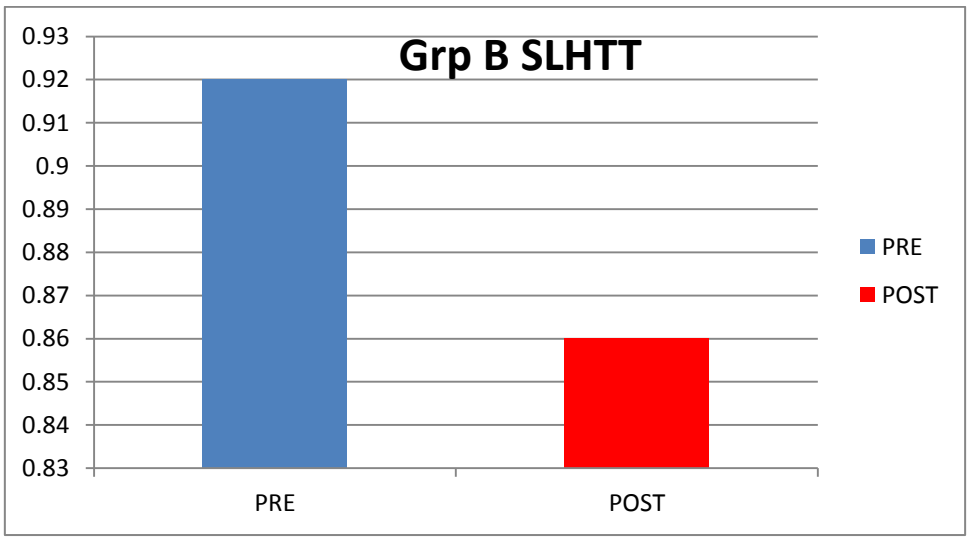


Table 9: COMPARISON BETWEEN POST FINDINGS OF SINGLE LEG HOP TIME TEST OF GROUP A & B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	-0.2667		0.4039	
2	19	-0.06316	-1.854	0.2694	0.072

- Difference -0.2035
- 95% confidential interval for difference: -0.4258 to 0.01874
- t = -1.854 with 38 degrees of freedom; P = 0.072

Table: 9 Shows comparison between post training of group A & B. The post mean of group A is -0.26 & that of group B is -0.06.the difference noted is -0.2. Applying the unpaired "t" test the P value obtained is 0.07. Thus statistically, there is no marked improvement of the SLHT in group A & B

Graph 9: COMPARISON BETWEEN POST FINDINGS OF SINGLE LEH HOP TIME TEST OF GROUP A & B

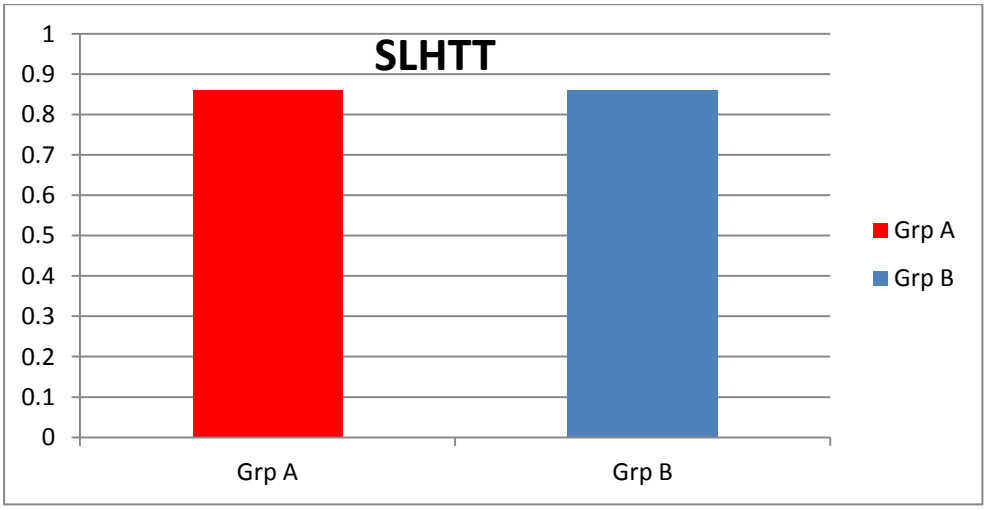


Table 10: COMPARISON OF PRE AND POST FINDINGS OF TRIPLE HOP TEST IN GROUP A

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	5.731		1.025	
2	21	5.864	-0.1329	1.087	0.010

- Difference -0.1329
- 95% confidential interval for difference: -0.2311 to -0.03477
- t = -2.825 with 20 degrees of freedom; P = 0.010

Table: 10 Shows pre & post training means of THT of Group A. Pre score is 5.73 mts & post score is 5.86 mts. The difference noted is 0.13. Using paired "t" test. The P value is 0.01 which is <0.05. Hence, statistically the test is significant. It shows that there is improvement in the THT after training on Inclined Board.

Graph 10: COMPARISON OF PRE AND POST FINDINGS OF TRIPLE HOP TEST IN GROUP A

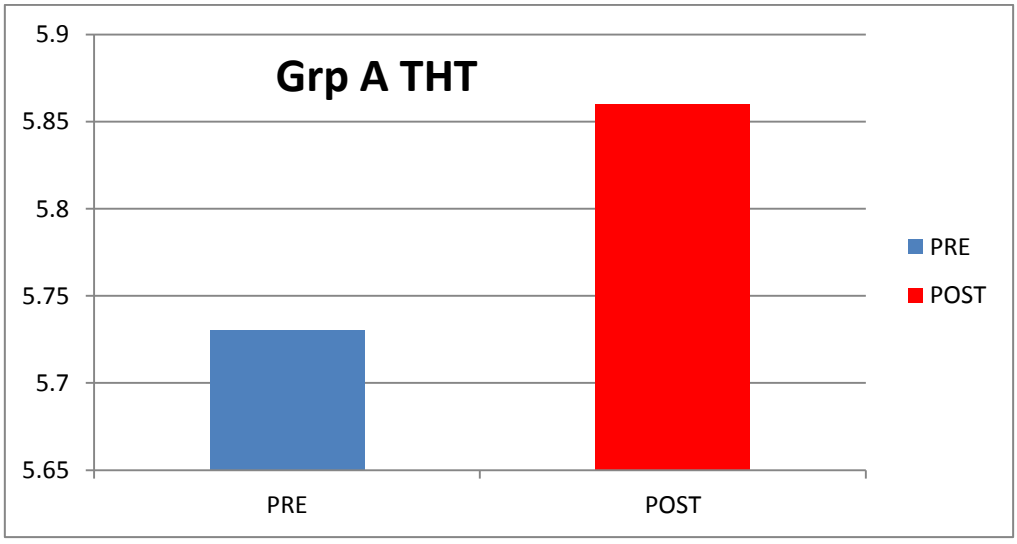


Table 11: COMPARISON OF PRE AND POST FINDINGS OF TRIPLE HOP TEST IN GROUP B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	19	6.297		1.131	0.000
2	19	-0.1037	27.840	0.3104	

- Difference 6.401
- 95% confidential interval for difference: 5.918 to 6.884
- t = 27.840 with 18 degrees of freedom; P = 0.000

Table: 10 Shows pre & post training means of THT of Group A. Pre score is 5.73 mts & post score is 5.86 meters. The difference noted is 0.13. Using paired "t" test. The P value is 0.01 which is <0.05. Hence, statistically the test is significant. It shows that there is improvement in the THT after training on Inclined Board.

Graph 11: COMPARISON OF PRE AND POST FINDINGS OF TRIPLE HOP TEST IN GROUP B

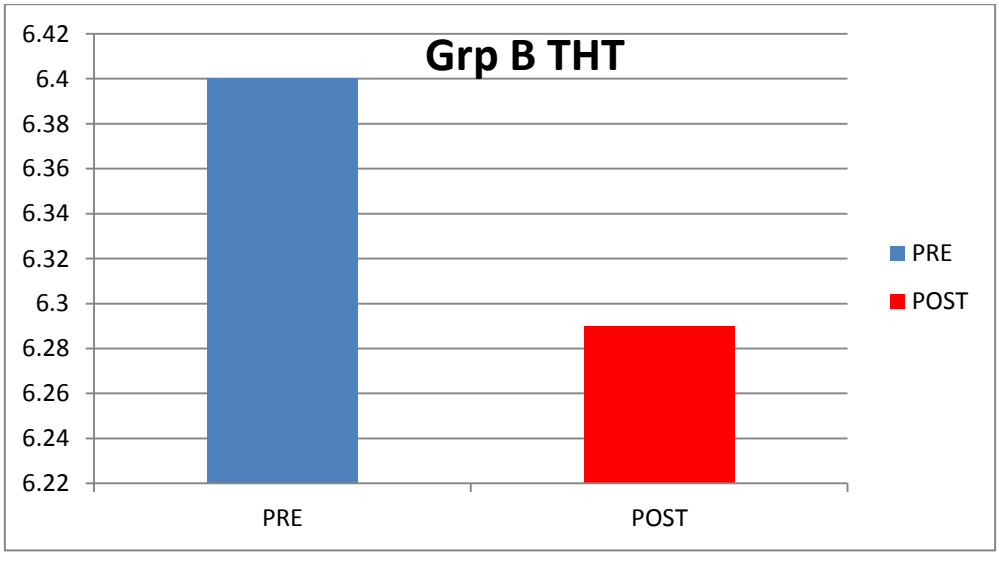


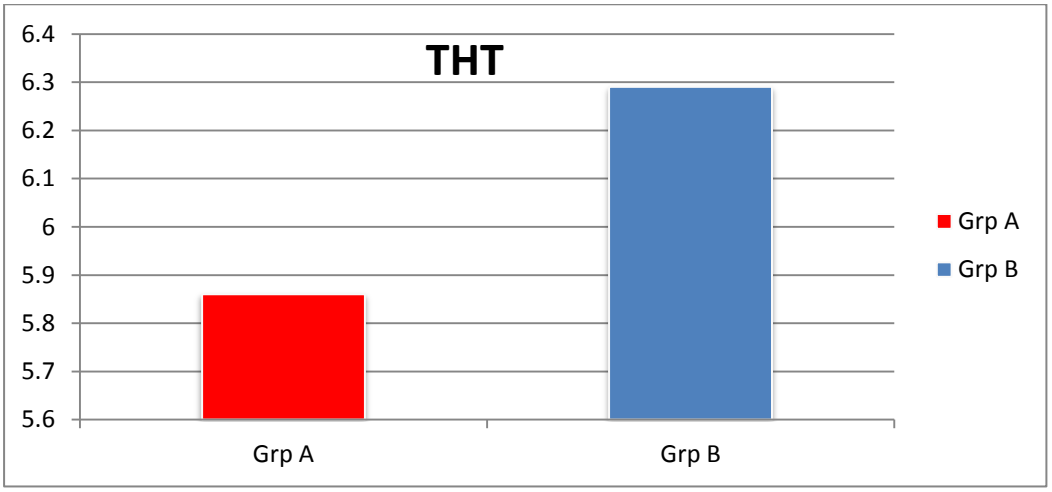
Table 12: COMPARISON BETWEEN POST FINDINGS OF TRIPLE HOP TEST OF GROUP A & B

Group	N	Mean (cm)	T value	Std Deviation	P value
1	21	0.1329	2.821	0.2157	0.008
2	19	-0.1037		0.3104	

- Difference 0.2365
- 95% confidential interval for difference: 0.0668 to 0.4063
- t = 2.821 with 38 degrees of freedom; P = 0.008

Table: 12 Shows post of group A & B for THT. The post scores are 0.13 for Group A & -0.10 for group B. The difference noted is 0.03. Applying the unpaired "t" test the p value obtained is 0.008 < 0.05. Thus, the test is significant. There is a significant increase in the THT of Group A in comparison to group B. Post the Inclined Board Plyometric training.

Graph 12: COMPARISON BETWEEN POST FINDINGS OF TRIPLE HOP TEST OF GROUP A & B



RESULT

Table: 1 Shows pre and post training mean of the vertical jump test of Group A. the pre training mean was 251.4 cm & post was 252.1 cm .So the difference was 0.7 cm. By using paired 't' test, the p value obtained is 0.267 which is >0.05 Thus it is proven statically that there is not much marked increase in the vertical jump height in group A after inclined board plyometric training.

Table: 2 Shows pre & post training of VJT in group B pre training mean was 253.7 cm & post 254.9 cm. The difference was 1.2 cm. By using paired "t" test the P value obtained was p= 0.320 which is >0.05. Thus there is not a much marked difference in the improvement of the VJ height in group B.

Table: 3 Shows a comparison between the post training of the group A & B of VJT. The difference is -0.5. By using unpaired "t" test, the P values obtained was p=0.70 which is >0.05. Thus, statically there is not much difference in the improvement of the VJ of Group A with Group B.

Table: 4 Shows pre & post training of SJT in group A. Pre training was 251.3 cm &post was 252.9cm.The difference obtained is 1.6 cm. By applying the paired "t" tests the P value obtained was 0.018 which is <0.05. This shows slight improvement in the static jump test in group A after the Inclined Board plyometric training.

Table: 5 Shows the pre & post training of SJT in group B. Pre training score was 254.7 cm & post was 255.5 cm. The difference noted was obtained was 0.508 which is >0.05. Thus statistically there is not much improvement in the SJ height in Group B.

Table: 6 Shows a comparison between post training of group A & B for SJT. The mean post of Group A is 1.61 & that of group B is 0.73. The difference between the two is 0.88. By using the unpaired "t" test, the P value obtained was 0.478 which is > 0.05 hence; statistically there is not a marked increase in the static jump performance of group A & B.

Table: 7 Shows pre & post training of SLHTT in group A. Pre score is 1.129 sec & Post score is 0.86 sec. The difference measured is -0.26. By applying the paired "t" test, the p value obtained is 0.007 which is <0.05. Thus statistically, the test is significant and there is a difference in the improvement of the pre & post training of the Inclined Board Plyometric training.

Table: 8 Shows pre &post training mean of SLHTT group B. Pre score is 0.923 sec & post score is 0.86 sec. The difference noted is -0.06. Using the paired "t" test, the p value obtained is 0.32>0.05. Thus this test is not improvement in the SLHTT of group B .there is no improvement in the SLHT of group B.

Table: 9 Shows comparison between post training of group A & B. The post mean of group A is -0.26 & that of group B is -0.06.the difference noted is -0.2. Applying the unpaired "t" test the P value obtained is 0.07. Thus statistically, there is a slight deviation in the improvement of the SLHT in group A & B.

Table: 10 Shows pre & post training means of THT of Group A. Pre score is 5.73 mts & post score is 5.86 mts. The difference noted is 0.13. Using paired "t" test. The P value is 0.01 which is <0.05. Hence, statistically the test is significant. It shows that there is improvement in the THT after training on Inclined Board.

Table: 11 Shows pre & post training mean of THT of group B. Pre mean score is 6.29 mts & post mean score is -0.10 mts. The difference is -6.29. Using the paired "t" test, the P value is 0.00. < 0.05. Thus the Test shows Significance in Group B.

Table: 12 Shows post of group A & B for THT. The post scores are 0.13 for Group A & -0.10 for group B. The difference noted is 0.03. Applying the unpaired "t" test the p value obtained is 0.008 < 0.05. Thus, the test is significant. There is a significant increase in the THT of Group A in comparison to group B. Post the Inclined Board Plyometric training.

DISCUSSION

This study was an attempt to investigate the effect of inclined board plyometric exercise training on the jump performance on young elite athletes. The subjects selected in the study were athletes involved in sporting activity for more than 1 year male as well as female players, between 15-25 years. The subjects had attained the maturity level, as this has been suggested as a prerequisite to be considered prior to the administration of the plyometrics, that the participant has reached a basic maturation level.

Since the procedures involved were dynamic in nature, the subjects were excluded from the study that had muscular pain, orthopaedic or neurological impairment, met with any kind of surgery or having any pathological or systemic disease.

Terese L. Chmielewski et al (2006) studied Plyometric exercises in the rehabilitation of athletes and suggested that, in Plyometrics there is loading of the joints, and the tissues has to tolerate high forces for the same reason, the athletes having any kind of acute inflammation or pain, immediate postoperative status, and joint instability were excluded from the study.[22]

Individuals fulfilling inclusion criteria were selected for the study. One Group was given Plyometric Training Program on a strong designed inclined board and others were given the same protocol but without the inclined board. Measurements of vertical jump height by vertical jump test and static jump test, distance by triple hop test and quickness by

single leg hop time test were taken before and after administration of training programs.

Much research has been focused on the development of vertical jump performance. Although various training methods, including heavy-resistance training, explosive type resistance training, electro stimulation training and vibration training, have been effectively used for the enhancement of vertical jump performance, most coaches and researchers seem to agree that plyometric training is a method of choice when aiming to improve vertical jump ability and leg muscle power.

Studies carried out by authors such as Blattner and Noble (1979) and Bosco (1982) have shown that Plyometric Training has a significant effect in increasing hip and thigh power that is measured by the vertical jump.[20]

Kannas et al reported a 10% increase in hopping height when performing the exercise on an inclined surface (15 degrees). The researchers found that the activity of both the soleus and tibialis anterior were significantly greater during the propulsion phase.[5]

Kannas et al compared groups of 10 athletes (all young males but no training history given) performing plyometric drills on an incline (15 degrees) or flat surface. Athletes performed 8 sets of 10 consecutive jumps on 4 days a week and for 4 weeks. The incline group showed significant improvements in fast depth jump performance (17% from a 20cm drop, 14% from 40cm) with activity of the gastrocnemius during the propulsion phase also increased during these jumps. While the incline group demonstrated a tendency for slight increases in squat,

countermovement and slow depth jump performances, these were not significant.[3]

Jefferson Eduardo Hespanhol, Leonardo Gonçalves da Silva Neto and Miguel de Arruda studied the reliability of the vertical jumping test. Eighteen male volunteer athletes participated in this study, and they were divided as follows: eleven handball players and seven basketball players. The assessed variables for the test and re-test were: power peak (PP), mean power (MP), and fatigue index (FI). The performances attained by them in these variables were measured through the vertical jumping test in four series of the 15-seconds test with 10 seconds recovery between series. The data analysis pointed out the existence of a reliable measurement of the IVJT when assessing the explosive strength resistance through the mean power and fatigue index variables.[31]

Table 3 shows a comparison between the post training of the group A & B of vertical jump test. Using the unpaired "t" test, the P values obtained was p=0.70 which is >0.05. Thus, statically there is not much difference in the improvement of the Vertical Jump of Group A with Group B.

Markovic G, Dizdar D, Jukic I, Cardinale M studied the reliability and factorial validity of squat (SJ) and countermovement jump (CMJ) tests. The aim was to compare 3 popular methods for the estimation of vertical jumping height. Physical education students (n = 93) performed 7 explosive power tests: 5 different vertical jumps (Sargent jump, Abalakow's jump with arm swing and without arm swing, SJ, and CMJ) and 2 horizontal jumps (standing long jump and standing triple jump). Thus, their result concluded that CMJ and SJ, measured by means of

contact mat and digital timer, are the most reliable and valid field tests for the estimation of explosive power of the lower limbs in physically active men.[14]

Table 4 shows a significant difference in the pre and post readings of static jump test in group A which is the experimental group. Using the "t" test the p value obtained was 0.018 which shows an improvement in the static jump performance in the experimental group.

R Tyler Hamilton, David H Perrin (2008) suggested that Single-leg hop tests were designed to assess functional performance. These functional hop tests are reported to require muscular strength, neuromuscular coordination, and joint stability in the lower limb and are considered useful in the clinical setting because they require minimal equipment and time.[13]

Noyes et al tested anterior cruciate ligament–deficient participants on 4 hop tests and found that 52% had abnormal limb symmetry during a single-leg hop test. However, they concluded that the tests were not able to detect the participant's specific functional limitations. That is, although limb asymmetries were noted, investigators were unable, from their study design, to determine the primary cause of abnormal function in injured participants (example, strength or balance deficits).

Table: 9 Shows comparison between post training of group A & B. Using the unpaired "t" test the p value obtained was 0.07. This proves single leg hop time test significant for group A in comparison to group B.

Sandra J Shultz, Randy J Schmitz (2008) said that Triple-hop distance was designed originally as a test for those recovering from injury or surgery to gauge readiness for activity and frequently has been reported to require a combination of muscular strength, power and balance. Their study demonstrated that THD is a strong predictor of lower limb muscular strength and power in a healthy soccer population and support its clinical usefulness as a preseason screening test. The result suggests that THD is a valid test of lower limb power and strength in National Collegiate Athletic Association Division I soccer players.[32]

Table: 12 Shows post readings of group A & B for Triple hop test. Applying the unpaired "t" test the p value obtained is $0.008 < 0.05$. Thus, the test is significant. There is a significant increase in the triple hop test of Group A in comparison to group B, Post the Inclined Board Plyometric training.

During a plyometric movement, the muscles undergo a very rapid switch from the eccentric phase to the concentric phase. This stretch-shortening cycle decreases the time of the amortization phase that in turn allows for greater than normal power production. The muscles stored elastic energy and stretch reflex response are essentially exploited in this manner, permitting more work to be done by the muscle during the concentric phase of movement. Training programs that have utilized plyometric exercises have been shown to positively affect performance in power-related movements such as jumping and speed. In the present study, improvements were seen in vertical jump height and vertical jump power.[8]

Better improvement can be seen on inclined plyometric training in addition to the above changes as the length of the Achilles tendon increases due to dorsiflexion and considering the length-tension relationship, more force production can be observed.

The increase in power following a plyometric training program could be due in part to increases in muscle fiber size. Improvements in muscle force production have been associated with increases in muscle fiber size. Study has shown that plyometric training can result in significant increases in both Type I and Type II muscle fiber area. The potential increase in muscle fiber size could account for the observed increases in body mass within the groups as well since there were no changes in percent body fat.[8]

Improved muscle performance due to a plyometric training program may also be due in part to increased motor unit functioning. Previous studies have indicated that neuromuscular adaptations such as increased inhibition of antagonist muscles as well as better activation and co-contraction of synergistic muscles may account for the improvements in power output.[8]

Yuri Verkhoshansky 2012 stated that performance during stretch shortening cycle exercise is influenced by the visco elastic properties of the muscle tendon units. During stretching of an activated muscle, mechanical energy is absorbed in the tendon structure (tendon & apponeurosis) and this energy can be subsequently re-utilized if shortening of the muscle immediately follows the stretching.[34]

Bosco and Komi 1982 found that increases in vertical jump ability following a Countermovement jump or Drop jump could be attributed to a combination of the utilization of elastic energy and the stretch reflex potentiation of the muscle activation. They concluded that the elastic phenomenon is probably of primary importance in this increase.[20]

Hence during inclined plyometrics, there is an increase in the angle of dorsiflexion.

Due to this increase, the length of the gastrocsoleus also increases. This further alters the torque of the muscle in comparison to the ankle in neutral of plane surface. This alteration of the length and torque of the muscle causes an improvement in the force production rendering improved jump performance.

CONCLUSION

Thus we conclude that inclined board plyometric training has an effect on the jump performance of the athletes and a significant improvement was seen on Static jump test, Single leg hop time test and Triple hop test after 4 weeks of training.

RECOMMENDATIONS

1. Larger sample size can be studied with other outcome measures.
2. Inclination of the board can be altered and result can be checked under similar parameters.
3. Torque of the hamstring and quadriceps muscles can also be considered in further studies.

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ANNEXURE

SUBJECT EXPLANATION FORM

PURPOSE OF STUDY:

This study is useful in finding the effect of inclined board plyometric training on jump performance in young elite athletes.

METHODS:

40 athletes were randomly selected from the Deccan Gymkhana F. C. Road, Pune and after signing of consent form they were evaluated and then were given 4 weeks inclined board plyometric training protocol in Group A (experimental) and Group B (Conventional) and later were reassessed.

(Investigator's Name)

APPENDIX 1: MASTERCHART

Gr	Sr.N	Age	Gender	VJT Pre (cm)	VJT Post (cm)	SJT Pre (cm)	SJT Post (cm)	SLHTT Pre (sec)	SLHTT Post (sec)	THT Pre (mt)	THT Post (mt)
A	1	18	F	250	252	248	250	0.68	0.78	5.15	5.26
A	2	17	F	229	231	228	230	1.17	0.79	4.48	4.64
A	3	17	F	250	250	251	249	1.49	0.93	4.99	4.93
A	4	16	F	253	253	251	252	0.98	0.77	5.04	5.1
A	5	23	F	252	256	252	256	0.62	0.7	5.26	5.39
A	6	25	F	243	242	242	242	0.63	0.74	5.16	5.22
A	7	18	F	250	244	246	246	0.75	0.63	5.48	5.7
A	8	15	F	225	225	227	225	1.53	1.06	5.16	5.37
A	9	19	F	251	252	249	254	0.64	0.76	5.71	5.28
A	10	20	F	242	243	240	246	0.85	0.88	5.83	5.78
A	11	15	F	210	217	209	218	1.14	0.84	3.69	4.03
A	12	16	F	252	250	254	254	0.69	0.76	5.35	5.35
A	13	18	M	258	257	262	259	0.78	0.96	7.36	7.76
A	14	19	M	257	258	258	258	1.83	0.74	6.87	7.0619
A	15	19	M	283	285	285	286	1.66	0.61	6.63	7.08
A	16	21	M	257	263	258	262	1.82	0.72	6.23	6.85
A	17	15	F	239	237	238	239	1.2	0.91	4.36	4.32
A	18	15	M	278	276	277	279	0.67	0.77	6.65	6.78
A	19	22	M	280	282	279	283	1.26	0.85	7.25	7.3
A	20	17	M	265	267	266	266	2.31	2.11	6.5	6.68
A	21	21	M	256	255	257	257	1	0.79	7.21	7.27
B	22	18	M	266	272	268	268	0.59	0.53	8.56	9
B	23	20	M	273	275	274	277	0.72	0.58	8.34	8.51

B	24	18	M	260	263	258	261	0.81	0.46	6.82	6.53
B	25	24	M	262	265	262	264	0.69	0.53	7.25	7.2
B	26	17	M	261	271	262	268	0.61	0.65	7.31	7.17
B	27	18	M	231	242	231	242	0.64	0.57	5.74	6.03
B	28	25	M	264	260	261	262	0.88	0.45	7.53	7.44
B	29	24	M	246	253	245	252	0.8	0.72	6.53	6.34
B	30	23	F	254	249	256	250	1.26	1.05	5.8	5.6
B	31	25	F	250	244	251	245	0.85	0.81	5.89	5.3
B	32	18	F	231	231	232	233	0.64	0.96	5.78	6.06
B	33	24	F	253	259	255	261	1.07	1.04	5.53	5.47
B	34	25	F	253	250	255	250	0.64	0.84	5.52	5.45
B	35	22	F	268	268	271	271	1.17	0.94	5.92	4.96
B	36	25	F	259	259	262	261	1.04	1.03	5.75	5.57
B	37	23	F	258	251	260	253	1.02	0.94	6.89	6.69
B	38	22	F	238	238	239	239	1.61	1.06	5.16	5.11
B	39	21	F	250	248	252	250	1.28	1.28	5.44	5.46
B	40	20	F	244	246	246	247	1.23	1.91	5.85	5.75

APPENDIX 2: CONSENT FORM

Title: - "To Study Effect Inclined Board Plyometrics on jump performance among Young Elite Athletes"

Participant: - I confirm that _____(investigator) has explained me the purpose of the research, the study procedure and the possible risks and benefits that I may experience. I have read and understood this consent to participate as a subject in this research project.

Name: - **Date: -**

Signature: –

INVESTIGATOR: –

I have explained to _____ the purpose of the research, the procedure required and the possible risk and benefits to the best of my ability. I have made every efforts to make the participant understand and cleared all questions put forward by her.

Name of the investigator Date: -

Signature

APPENDIX 3: DATA RECORDING CHART

Name:

Age: Sex:

Date of Examination:

1. Completed at least 1full year of competitive athletics. – Yes / No
2. Involved in any professional sporting activities.- _____
3. History of Lower limb and Spine fractures and deformities. – Yes / No
4. Tightness of Hams / Quads/ Iliopsoas /TFL/ ITband /Calf/ : Yes / No
5. Any intrinsic complains by the athlete that limits the athletic performance._____ _____

Subject fitting to criteria – Yes / No

Signed the informed consent: Yes / No

Score Sheet:

Scoring / Training	PRE TRAINING				POST TRAINING			
Trials	TRIAL 1	TRIAL 2	TRIAL 3	AVE	TRIAL 1	TRIAL 2	TRIAL 3	AVE
Date	DATE	DATE	DATE		DATE	DATE	DATE	
VERTICAL JUMP TEST (Ft)								
STATIC JUMP TEST (Ft)								
SINGLE LEG HOP TIME TEST (Sec)								
TRIPLE HOP TEST (Ft)								

Signature of Participant Signature of Investigator

APPENDIX 4: PHOTOGRAPHS

3. SUBJECT READY FOR TRIPLE HOP TEST

1. SUBJECT READY FOR STATIC JUMP TEST AND VERTICAL JUMP TEST

2. SUBJECT READY FOR SINGLE LEG HOP TIME TEST

3. SINGLE LEG JUMPS ON THE INCLINED BOARD

4. DOUBLE LEG JUMPS ON THE INCLINED BOARD

5. RUNNING WITH ALTERNATE LEGS ON THE INCLINED BOARD

6. DOUBLE LEG DOUBLE JUMPS ON THE INCLINED BOARD

ABSTRACT

Title- To Study the Effect of inclined board plyometric training on jump performance in young elite athletes. **Objectives:** To compare the Effect of inclined plyometric training and plane surface plyometric training. **Methodology**-All the subjects were randomly selected from the Deccan Gymkhana F. C. Road, Pune and after signing of consent form they were evaluated and then were given 4 weeks inclined board plyometric training protocol in Group A (experimental) and Group B (Conventional) and later were reassessed. **Results** - 40 subjects completed the study. Comparison of pre and post Of SJT, SLHTT, THT in Group A was found to be statistically significant and that of Group B SJT, SLHTT, THT was found to be statistically significant. Comparison of VJT was found statistically insignificant between group – A & group – B ($p>0.05$). **Conclusion**- This Study concludes that inclined board plyometric training has an effect on the jump performance of the athletes and a significant improvement was seen on Static jump test, Single leg hop time test and Triple hop test. **Key words-**Inclined board plyometrics, Optimum length tension relationship, Jump performance.

MANUSCRIPT

TO STUDY THE EFFECT OF INCLINED BOARD PLYOMETRIC TRAINING ON JUMP PERFORMANCE IN YOUNG ELITE ATHLETES

INTRODUCTION

POWER is the king of the sporting world. Plyometrics are a type of exercise designed to produce fast and powerful movements. They are generally used by athletes to improve performance in sports, especially those that involve speed, quickness and power.[1]

Two forms of plyometrics have been evolved. The first version of plyometrics was created by Yuri Verkhoshansky where he defined it as shock method. In this the athlete would drop down from a height and experience a "shock" on landing. This in turn would bring about a forced, involuntary eccentric contraction which would then immediately get switched to concentric contraction as the athlete jumped upward. The landing and takeoff time would be executed in an extremely short period of time, the range of 0.1- 0.2 seconds.[2]

The second version of plyometrics, seen to a very great extent in the United States, relates to doing any and all forms of jumps regardless of execution time. Such jumps cannot be considered truly plyometric since the intensity of execution is much less and the time required for transitioning from the eccentric to the concentric contraction is much greater. Speed and strength are integral components of fitness found in varying degrees in all athletic movements. Simple combination of speed and strength is power.[2]

There are many benefits that can be gained through plyometric exercise:

- They help to achieve any athletic goal.
- They give legs and muscles intense exercise which guarantees to increase muscle potential.
- An increased muscular endurance an ability to burn calories would come to great use for someone hoping to build a weight loss routine.
- It builds up explosive amounts of intense energy.
- It does not require any expensive exercise equipment. Anything that is needed can be easily found lying around the house.
- Plyometric exercising is simply utilizing the muscular energy that it takes to jump at one's own exercising advantages.[2]

The ankle joint proposes of 15 to 25 degrees of dorsiflexion and 30 to 50 degrees of plantar flexion. In such a case when the movement is done on an inclined surface, the plantar and the dorsiflexion both are altered. This improves the range of motion of the ankle joint and helps in the jump performance of the athlete.

The Stretch-Shortening Cycle

All plyometric movements involve **three** phases. The first phase is the pre-stretch or eccentric muscle action. Here, elastic energy is generated and stored. The second phase is the time between the end of the pre-stretch and the start of the concentric muscle action. This brief transition period from stretching to contracting is known as the **amortization** phase. The shorter this phase is, the more powerful the subsequent muscle contraction will be. The third and final phase is the actual muscle contraction. In practice, this is the movement the athletes desires the powerful jump or throw. This sequence of three phases is called the

stretch-shortening cycle. In fact, plyometrics could also be called stretch-shortening cycle exercises.[3]

Simple way to demonstrate the effect of the stretch-shortening cycle is to perform two vertical jumps. During the first vertical jump the athlete bends the knees and hips (eccentric muscle action or pre-stretch) and holds the semi-squat position for 3-5 seconds before jumping up vertically (concentric contraction) as high as possible. The 3-5 second delay increases the amortization phase. On the second jump the athlete bends the knees and hips to the same degree but immediately jumps up without a delay. This keeps the amortization phase to a minimum and makes best use of the stored elastic energy. The second jump will be higher.[3-4]

Modifications in the joint range of motion when performing a vertical jump could alter the range of muscle or tendon length during the movement. The behavior of the medial gastrocnemius (MGAS) fascicles has been described as a ‘‘catapult action’’ Particularly, the medial gastrocnemius fascicle length decreases at the instant of initial contact, it remains relatively constant during the braking phase followed by a decline during propulsion Simultaneously, the ankle is initially in semi neutral position and then it is plantar flexed. However, it is known that isometric medial gastrocnemius force production is affected by muscle length and, in turn, by the angle of the ankle joint. Thus, the position of the ankle joint is of great importance for force production.[4]

The need for the generation of higher joint power output during performance of dynamic activities leads to force – length relationship of the plantar flexors during consecutive stretch shortening cycles of hopping.[5]

During jumping, medial gastrocnemius produces a large amount of force at a slow velocity because its length remains close to optimum range. However, the amount of force produced by the medial gastrocnemius could be much greater if jumping technique can be modified such that the muscle works at a length range near to its maximal force potential.[5]

METHOD

Participants

A total of 25 subjects who fulfill Criteria, were participated in this study. Subjects were recruited from Perambalur District Sports Hostel. All subjects met the following inclusion criteria: 1) Athletes with the age group of 15 yrs and above. 2) Athletes who have completed at least 1 full year of competitive athletics. 3) Subjects with good flexibility and strength of lower limbs. 4) Subjects who have been involved in any professional active outdoor sporting activities involving running, jumping and speed movements. Subjects were excluded with following exclusion criteria: 1) Lower limb and Spine fractures and deformities. 2) Tightness and contractures of muscles n tendons of lower limbs. 3) Any intrinsic complains by the athlete that limits the athletic performance.

Study Design

Forty subjects were randomly allocated to two groups by the investigator who was involved in data collection, treatment implication, and data analysis. 46 subjects were targeted, out of which 40 were included for the study purpose. Subjects in group A received inclined board plyometric training exercises. While subject in group B did their conventional training on plane surface. Both the groups received this protocol for a period of one month, with a frequency of 4 times in a week. Baseline assessments were done after randomization, at the start of the protocol

and at the end of 4 weeks. For each subject, all assessment sessions were performed at the same time of day.

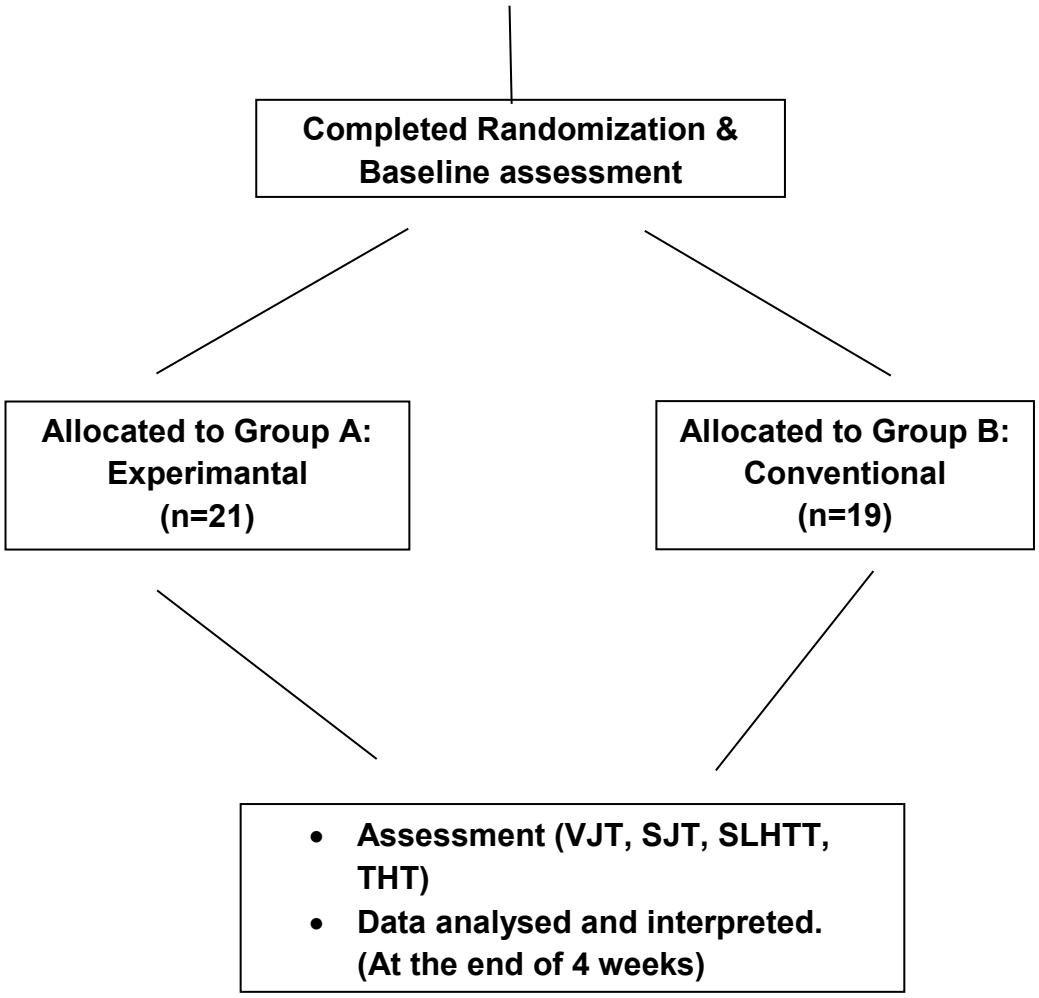


Fig 1. Study design and flow of the participants through each stages of the trial.

Assessment

VJT (Vertical jump test), SJT (Static jump test), SLHTT (Single leg hop time test) and THT (Triple hop test) assessed at baseline & at the end of 4 weeks.

Rehabilitation program

The rehabilitation program consisted of 16 sessions, each 1 hour long, 4 times weekly for 4 weeks. All treatment sessions occurred approximately at the same time of day on the same 4 days of the week throughout the study. Intervention was conducted in group and not in an individual format. The physical therapist was involved in performing the intervention as well as conducting the assessments. Duration- 4 weeks of training, 4 times per week i.e. 16 sessions per patient, an exercise was terminated, on patients demand if they feel tired or fatigue or any complains. Appropriate rest pause between each exercise was given. Total treatment duration 15 to 20 minutes. Inclined board plyometric training was given to Group A and Group B was given the same exercises on the plane surface.

Outcome Measure

VJT & SJT

The vertical jump test was conducted by placing a measuring tape vertically and the subjects were asked to jump against it. The static jump test and the vertical jump test were performed and recorded at the same time. The tests were done by asking the subjects to stand opposite to the vertical measuring tape. Then they were asked to squat for 5 seconds and jump as high as possible and touch the tape. Chalk powder was applied to each subject before they jumped and touched the tape. A person was

asked to sit on a high seated chair beside the measuring tape and record the jump height. Two jumps were performed together consecutively. The first test was the static jump test which was done by squatting for 5 seconds and jumping while the second test was done immediately by jumping again as high as possible after landing from the static jump test. These tests were to measure the power and strength of the lower limbs.

SLHTT

In this test the time in seconds was noted while the subject performed three trials of single leg hop jump. Quickness was tested in this test.

THT

In this test the horizontal distance was measured by the measuring tape as the subjects finished three trials of continuous three hops without a break. The distance at the end of the third hop was measured in every trial.

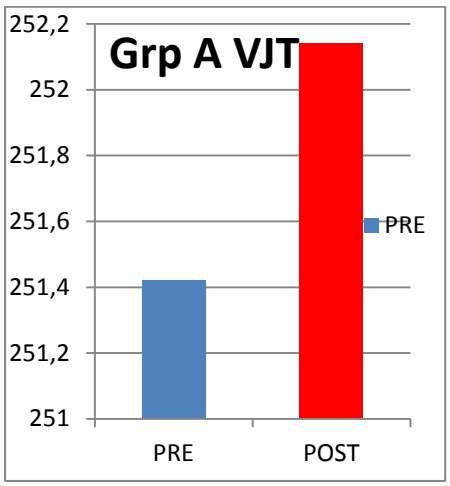
STATISTICAL ANALYSIS

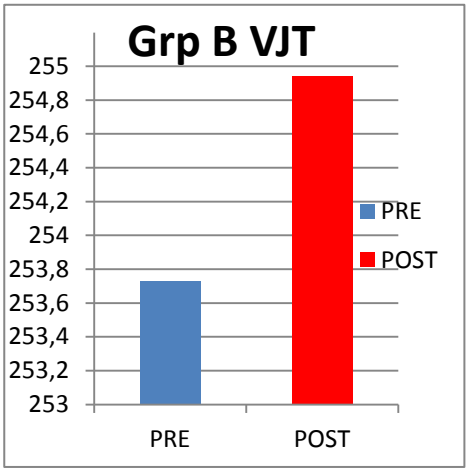
Data was analyzed by using Primer software and normality distribution done by Epi Info 7 software.

The Test of Significance such as “t” test between the groups was used after verifying the Bartlett’s Test for Inequality of Population Variances was not significant. In case of Paired Values the Pittman’s Test was used For Equality of Variances Before using the Paired “t” test. The statistical analysis was done using paired “t” test and unpaired “t” test. Intergroup significance was calculated by using unpaired “t” test and intragroup significance was calculated by paired “t” test. Data analysis was done and four test, (Vertical jump test, Static jump test, Single leg hop time test and Triple hop test) were recorded and tabulated.

The finding of present study clinically supports our alternative hypothesis that inclined board plyometric training (Group A) is effective in comparison to place surface exercise training. Our results reveal significant improvements in SJT, SLHTT and THT in both groups. No significant differences between groups were found in VJT and the between group difference was not significant statistically.

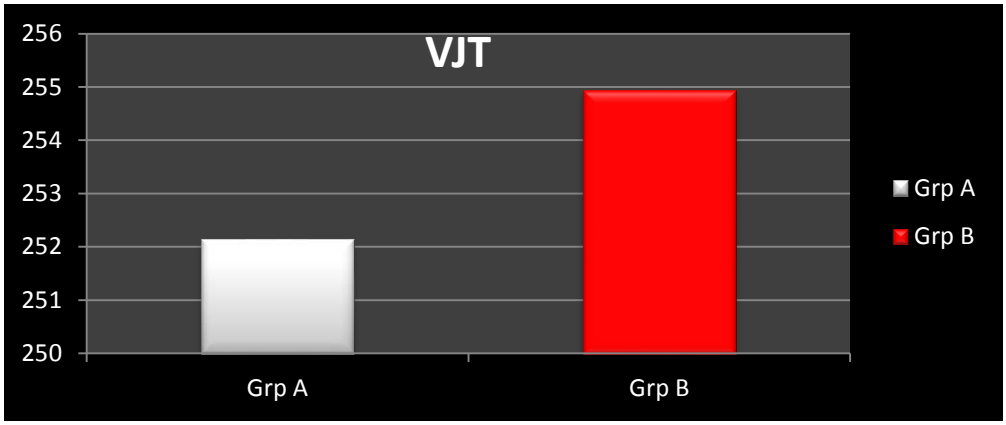
Following are the graphs representing distribution of inter group and intra group comparison of VJT, SJT, SLHTT and THT score respectively.



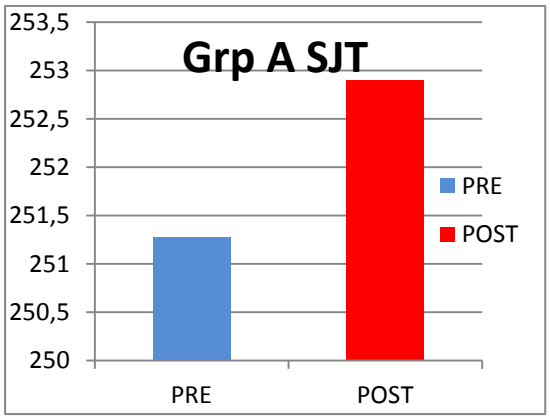


Graph:1 Comparison of pre and post findings of vertical jump test in group-A

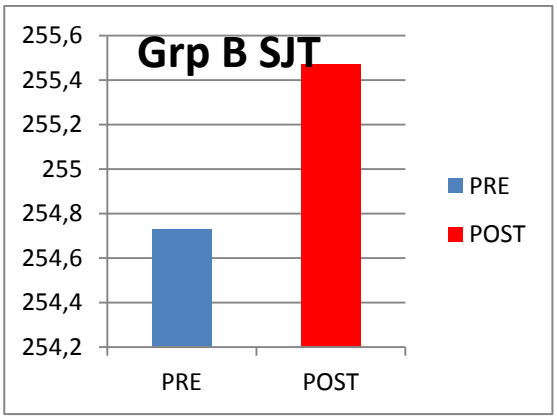
Graph:2 Comparison of pre & post findings of vertical jump test in group B



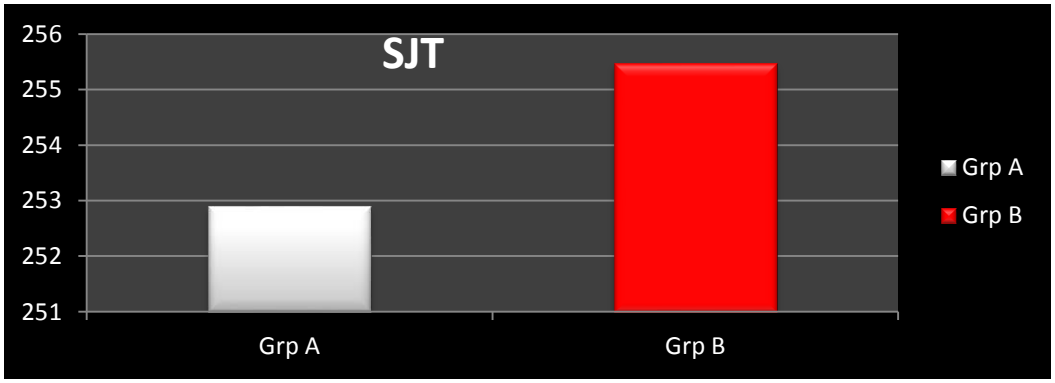
Graph:3. Comparison between post findings of vertical jump test of group A & B



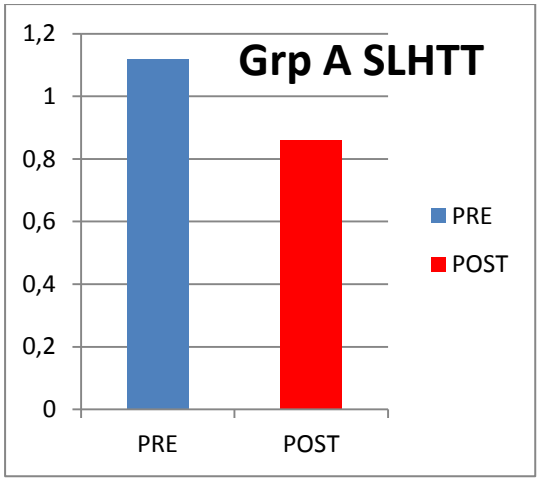
Graph: 4 **C**omparison of pre and post findings of static jump test in group-A



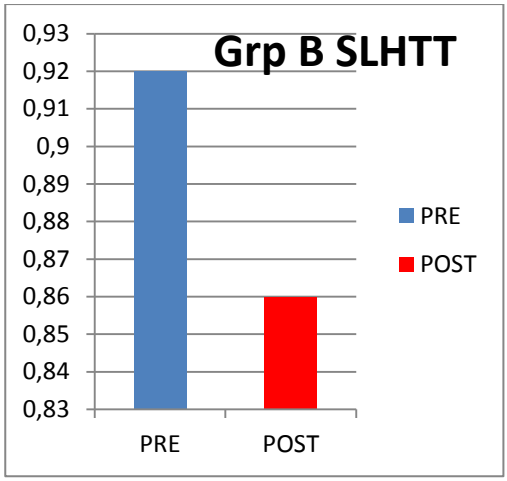
Graph:5 Comparison of pre & post findings of static jump test in group B



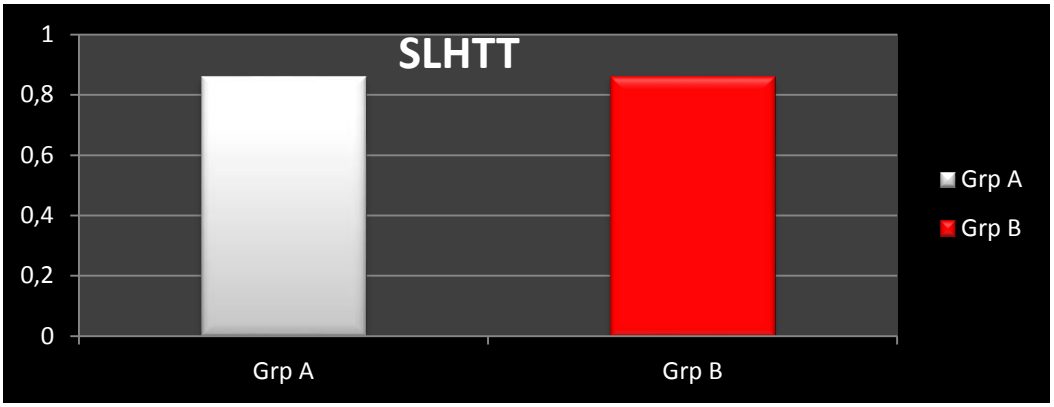
Graph: 6 Comparison between post findings of static jump test of group A & B



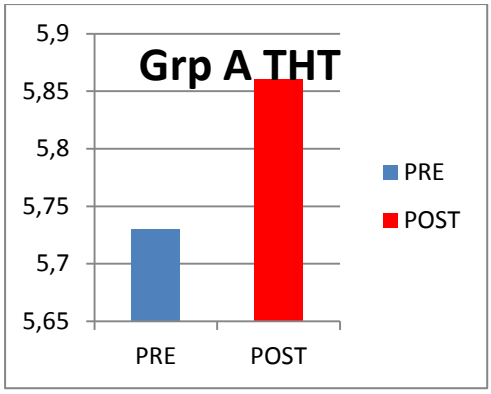
Graph:7 Comparison of pre and post findings of SLHT test in group-A



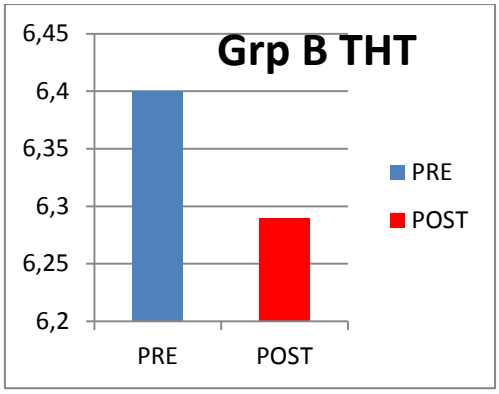
Graph:8 Comparison of pre & post findings of SLHT test in group B



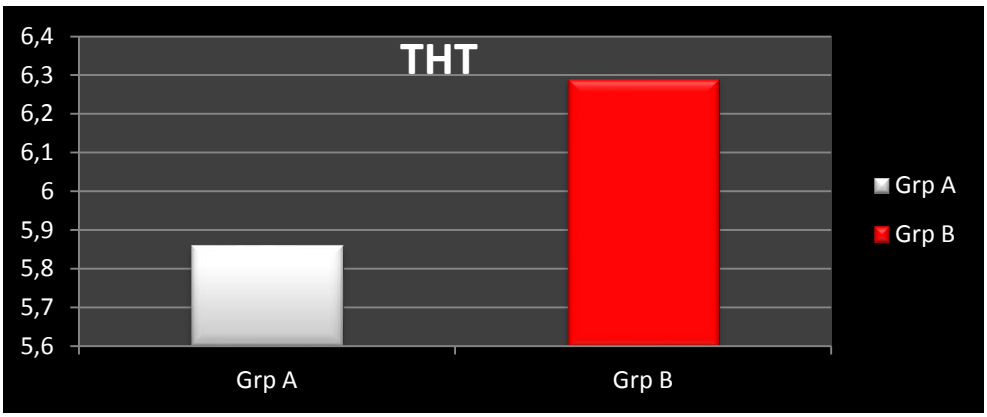
Graph: 9 Comparison between post findings of SLHT test of group A & B



Graph: 10 Comparison of pre and post findings of triple hop test in group-A



Graph:11 Comparison of pre & post findings of triple hop test in group B



Graph: 12 Comparison between post findings of triple hop test of group A & B

RESULT

40 subjects completed the study. Comparison of pre and post Of SJT, SLHTT, THT in Group A was found to be statistically significant and that of Group B SJT, SLHTT, THT was found to be statistically significant. Comparison of VJT was found statistically insignificant between group – A & group – B ($p>0.05$).

DISCUSSION

This study was an attempt to investigate the effect of inclined board plyometric exercise training on the jump performance on young elite athletes. The subjects selected in the study were athletes involved in sporting activity for more than 1 year male as well as female players, between 15-25 years. The subjects had attained the maturity level, as this has been suggested as a prerequisite to be considered prior to the administration of the plyometrics, that the participant has reached a basic maturation level.[6]

Terese L. Chmielewski et al (2006) studied Plyometric exercises in the rehabilitation of athletes and suggested that, in Plyometrics there is loading of the joints, and the tissues has to tolerate high forces for the same reason, the athletes having any kind of acute inflammation or pain, immediate postoperative status, and joint instability were excluded from the study. [6]

Much research has been focused on the development of vertical jump performance. Although various training methods, including heavy-resistance training, explosive type resistance training, electro stimulation training and vibration training, have been effectively used for the enhancement of vertical jump performance, most coaches and researchers seem to agree that plyometric training is a method of choice when aiming to improve vertical jump ability and leg muscle power.

Kannas et al compared groups of 10 athletes (all young males but no training history given) performing plyometric drills on an incline (15 degrees) or flat surface. Athletes performed 8 sets of 10 consecutive jumps on 4 days a week and for 4 weeks. The incline group showed significant improvements in fast depth jump performance (17% from a

20cm drop, 14% from 40cm) with activity of the gastrocnemius during the propulsion phase also increased during these jumps.While the incline group demonstrated a tendency for slight increases in squat, countermovement and slow depth jump performances, these were not significant.[7]

During a plyometric movement, the muscles undergo a very rapid switch from the eccentric phase to the concentric phase. This stretch-shortening cycle decreases the time of the amortization phase that in turn allows for greater than normal power production. The muscles stored elastic energy and stretch reflex response are essentially exploited in this manner, permitting more work to be done by the muscle during the concentric phase of movement. Training programs that have utilized plyometric exercises have been shown to positively affect performance in power-related movements such as jumping and speed. In the present study, improvements were seen in vertical jump height and vertical jump power. Better improvement can be seen on inclined plyometric training in addition to the above changes as the length of the achillis tendon increases due to dorsiflexion and considering the length-tension relationship, more force production can be observed.[8]

The increase in power following a plyometric training program could be due in part to increases in muscle fiber size. Improvements in muscle force production have been associated with increases in muscle fiber size. Study has shown that plyometric training can result in significant increases in both Type I and Type II muscle fiber area. The potential increase in muscle fiber size could account for the observed increases in body mass within the groups as well since there were no changes in percent body fat.[8]

Improved muscle performance due to a plyometric training program may also be due in part to increased motor unit functioning. Previous studies have indicated that neuromuscular adaptations such as increased inhibition of antagonist muscles as well as better activation and co-contraction of synergistic muscles may account for the improvements in power output.[8]

Yuri Verkhoshansky 2012 stated that performance during stretch shortening cycle exercise is influenced by the visco elastic properties of the muscle tendon units. During stretching of an activated muscle, mechanical energy is absorbed in the tendon structure (tendon & apponeurosis) and this energy can be subsequently re-utilized if shortening of the muscle immediately follows the stretching.[10] Bosco and Komi 1982 found that increases in vertical jump ability following a Countermovement jump or Drop jump could be attributed to a combination of the utilization of elastic energy and the stretch reflex potentiation of the muscle activation. They concluded that the elastic phenomenon is probably of primary importance in this increase.[9]

Hence during inclined plyometrics, there is an increase in the angle of dorsiflexion.

Due to this increase, the length of the gastrocsoleus also increases. This further alters the torque of the muscle in comparison to the ankle in neutral of plane surface. This alteration of the length and torque of the muscle causes an improvement in the force production rendering improved jump performance.

CONCLUSION

Thus we conclude that inclined board plyometric training has an effect on the jump performance of the athletes and a significant improvement was seen on Static jump test, Single leg hop time test and Triple hop test.

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